THE

ONTARIO WATER RESOURCES

COMMISSION

# BASIC DISTRIBUTION SYSTEM

# AND

# DEEP WELL OPERATORS' COURSE 1

NOVEMBER 3 - 7, 1969

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# PART I

# OPERATION AND MAINTENANCE

# OF

# DISTRIBUTION SYSTEMS

# TYPES, USES, PROTECTION, LAYING AND PRESSURE TESTING OF PIPE

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## INTRODUCTION

In the time at our disposal today, the various types of pipe used for underground water pipe lines will be considered from the point of view of the operation of a water works distribution system.

Some of you may have seen water mains composed of bored out logs laid end to end or, you could have come upon wood main stops driven into a hole in a metal water main to connect the service piping. There are still wood stave water transmission mains in service carrying water from mountain streams to towns in New England near the Quebec border.

A list of the types of pipe commonly used today for new water works installation would not include lead, wood or wrought iron; it would include gray cast iron, steel and copper along with pipe made of asbestos-cement, reinforced-concrete, ductile iron and several types of plastic material. The use of many of these pipe materials is limited to particular applications.

Precautions to be observed during construction will vary, as will protective measures and pressure testing procedures required for the various materials and applications.

## TYPES, USES AND PROTECTION OF PIPE

### Cast Iron, Gray and Ductile

There are cast iron water mains still in service in France which were installed over two hundred years ago. Cast iron distribution mains over one hundred years old are still being used in Montreal.

Until about fifty years ago, cast iron pipe was cast in sand moulds. From about 1920 to the present time most cast iron pipe has been produced by centrifugal casting in metal moulds by what is known as the Delavaud process, providing greatly improved strength and uniform wall thickness which makes pipe easier to cut or machine.

When a magnesium alloy is added to molten gray iron, in the proper proportions, graphitic or nodular iron is produced. This is commonly known as ductile iron.

Ductile cast iron pipe is much tougher than gray iron pipe. The plasticity of ductile iron combined with its high strength and corrosive resistance have been instrumental in making it a more popular pipe material than gray iron in the past three years.

Cast iron is frequently chosen for underground water pipes in sizes from 4" to 20" in diameter; and for treatment plant and pumping station piping, cast iron mains up to 48" in diameter are fairly common.

Rubber gasketed mechanical joints are usually used for cast iron fittings. Rubber gasketed bell and spigot slip-on type joints have become the most popular for cast iron distribution mains.

Flanged joints are usually used for in plant cast iron piping, but flanges are too rigid and expensive to be practical for use on underground piping.

Bell and spigot joints sealed with calked lead are still used occasionally. Sulphur compounds were used in many systems instead of lead as jointing materials. Some of these sulphur compounds never stop expanding, and the force due to expansion combined with the corrosive weakening of the pipe will sometimes cause the bells to split.

Mechanical joint gray cast iron fittings are usually used on both gray cast iron and ductile iron mains. Tyton joint fittings are used in some areas, and ductile iron fittings are available for installation under particularly severe conditions.

A thin cement mortar lining can be applied at the foundry when requested in all cast iron pipe. This lining is very effective in protecting against build up of tuberculation, and in maintaining high flow characteristics of the water main.

Bituminous enamel is applied at the foundry to both inside and outside of cast iron pipe.

Steel

Steel has been used as a water main material for many years. The strength and ease of handling of steel pipe have helped to make it popular in areas where corrosive ground conditions do not prevail.

Large water transmission mains are sometimes constructed of welded joint steel pipe with a complete poured concrete enclosure, and with a concrete lining applied and trowelled in place with special machines.

Rubber gasketed "stab" type bell and spigot joints are available on steel water pipe, making installations possible without special welding crews.

There are many bituminous and plastic compounds used for lining and outside protection of steel pipe, but thorough external protection is very difficult to attain without the use of a well designed cathodic protection system.

It is not practical to protect a pipe with cathodic protection unless the pipe is first protected by use of a good quality coating material properly applied. This should include taping or painting protective coating on joint components, particularly on welded joints. An uncoated bare pipeline would require large magnesium anodes or heavy rectifiers placed at frequent intervals along the pipe. One of the problems encountered with these heavy cathodic protection systems is that surrounding or crossing pipes can be damaged by the relatively high currents created in the earth. The object of coating first, then applying light cathodic protection is simply to protect the small areas on the pipe which fail to get the proper application of mechanical protection and to protect areas where the coating becomes damaged.

Cathodic protection systems are most effective on welded joint pipe lines. They are practically useless on rubber gasket jointed mains where good joint bonds are not installed.

Asbestos - Cement

There are two basic methods by which asbestos-cement is manufactured. In the older of these methods, the ingredients, consisting principally of cement and asbestos fiber are mixed thoroughly and cured while submerged in water. The other more modern type, composed principally of portland cement, finely ground silica and asbestos fiber, is cured in a pressurized, saturated steam atmosphere in an autoclave.

Asbestos-cement pipe is used for distribution mains and the smaller feeder mains. Its corrosion resistance and ease of handling and installation have helped it to become more popular, particularly in areas where soil conditions are stable, but highly corrosive.

Extra care should be exercised to be certain that asbestos-cement pipe is properly bedded during construction to avoid uneven settlement and the resultant over stressing of parts of the pipe.

Joints are sealed on asbestos-cement pipe by use of slip-on type rubber gasketed joints.

Cast iron valves and other fittings are available for use on asbestos-cement water mains.

Reinforced-Concrete

Reinforced-concrete pipe is used principally for feeder and transmission mains, sixteen inches and larger in size. It is very durable and has the advantage of being relatively economical and easy to install along with the advantage of retaining its high flow capacity.

Joints on reinforced-concrete pipe are usually sealed by the use of a slip-on type rubber gasketed bell and spigot connection.

Fittings for reinforced-concrete pipe are usually fabricated in a fashion similar to the manufacturing of the pipe or, the pipe is frequently made with one end adapted to couple up to a flange or standard mechanical joint. Pipe ends to fit various Victaulic and Dresser fittings are also available. By careful selection of pipe ends it is possible to use valves on reinforced-concrete mains which can be readily removed from the line for service.

Reinforced-concrete pipe is not practical for use on a main which could require the connection of a large number of service pipes.

Plastic

There are numerous types of plastic pipe available from hundreds of manufacturers.

Fibreglass reinforced plastic pipe has been used for years for transferring chemicals, and pipe made of polyvinyl chloride, commonly called PVC, is gaining acceptance as water pipe. Polyethylene pipe is being used as a pipe material for small sized piping for water services, lawn watering networks and the like.

Some types of PVC pipe materials have been found to contain lead in many times the concentration permitted under the United States Public Health Service Drinking Water Standards.

There is an AWWA Committee at work now developing a standard for selections and installation of plastic pipe water mains and services.

Before we adopt the use of plastic pipe for carrying the carefully treated product of our water plants, we should be certain that the pipe has been approved by an independent testing agency.

PVC pipe is available now capable of retaining cold water up to 160 P.S.I. in sizes up to eight inches in diameter. Polyethylene pipe in sizes up to twenty inches in diameter is available for low pressure service.

The coefficient of expansion of Type I PVC is approximately five times that of iron pipe. It is therefor adviseable to provide for the expansion and contraction of plastic pipe to avoid excessive stresses at changes in direction and branches.

Polyethylene pipe is joined by use of mechanical clamps or in the larger sizes by thermal fusion in which case the ends of pipe to be joined are heated to fusion temperature, then quickly held together and allowed to cool.

PVC pipe is joined either by solvent welding, which involves use of a coupling and a solvent cement, or by using a bell and spigot rubber gasket arrangement similar to those used on cast iron pipe.

## PIPE LAYING AND PRESSURE TESTING

### Pipe Laying

Your experience with maintenance of water mains will likely have led you to the conclusion that care and attention to details during construction will pay great dividends in the way of trouble free performance later.

These later problems can be directly caused by several common construction failures.

The handling of pipe from the time it arrives on the rail car or transport is a very critical area, requiring caution not only in unloading pipe to be sure it is not damaged, but also, care must be taken in stockpiling, in transporting to the trench, and in lowering to the trench bottom. Care during this operation can prevent leaks occuring later in damaged cast iron or asbestos cement pipe, it can prevent concrete linings from being cracked; care at this stage can also prevent trouble from dirt or even small animals from being trapped in the pipe.

The trench must be dug in accordance with the Trench Excavator's Protection Act to insure the safety of the workmen.

Pipe manufacturers instructions for the joining of pipe sections are available for each specific joint type. These outlines must be strictly adhered to. Seemingly small details such as using improper gasket lubricant or using plastic pipe solvent intended for another type of pipe which may look similar can, produce deep trouble later.

The proper blocking of fittings, bends and dead ends on any pipeline is extremely important. The particualr type of pipe could dictate a pipe choice under some circumstances. End thrust on high pressure transmission mains larger than 30 inches in diameter frequently exceeds one hundred tons.

Careful bedding of each length of water main pipe is of paramount importance if years of trouble free performance of the main is expected. All types of pipe must be supported properly by the trench bottom and to a lesser degree by the backfill material.

Most pipe can be laid directly on the trench bottom if the bottom has been levelled properly.

For pipe laid on rock, soft or very wet ground, or on soil having inadequate bearing properties, special bedding consisting usually of gravel or crushed stone must be provided to support the pipe throughout its entire length. An area at the pipe joint, large enough to provide space for the bell or joint collar, and for the pipe layer to perform the jointing operation, must be provided.

Rock free backfill should be placed in six inch tamped layers, evenly on both sides of the pipe to at least twelve inches over the top of the pipe.

If possible, joints should be left exposed until leakage tests have been completed.

The remainder of the backfilling should be done to the satisfaction of the road authority; or to the satisfaction of the property owner if the main is not being installed in a road allowance.

Pressure Testing

Leakage tests should not be commenced until the main has been under pressure for at least 24 hours with all air released from high points and dead ends.

AWWA standards are available to describe the procedures and establish allowable leakage for the various types and sizes of water main pipe.

The acceptable leakage on cast iron pipe mains, of either gray iron or ductile iron, for 18 foot lengths of pipe may be simply calculated at 20 imperial gallons per day per inch diameter of pipe per mile of pipe being tested, at pressure of 150 p.s.i., if mechanical or tyton joints are used. Under similar circumstances the allowable leakage on asbestos cement pipe would be greater than this because with shorter pipe lengths, more joints would be involved.

The accurate measurement of make-up water required to maintain test pressure, should be continued for at least two hours after any repairs necessary to cut down leakage to acceptable levels have been completed.

Regardless of the type of pipe which is selected for a water main, the quality of service obtained from the main for its entire life will be greatly influenced by the tender care and careful attention given to the details of pipe handling and installation.

# DISINFECTION OF WATER SYSTEMS AND APPURTENANCES

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## GENERAL

The installation of new water mains and equipment or the repair of broken mains and appurtenances may lead to contamination of a water supply if an adequate disinfection programme is not undertaken. Such a programme must include precautionary construction practices, suitable flushing and chlorination of the affected portion of the system, and bacteriological testing to determine the adequacy of the disinfection programme.

Not only is disinfection employed to protect the health of the consumer but it is also required to prevent the growth in the system of various water-borne nuisance organisms. Thus, although disinfection is carried out primarily for the destruction of disease-causing bacteria, it is also used for the elimination of non-pathogenic micro-organisms which can cause colour, taste and odour problems.

## DISINFECTION OF NEW MAINS AND APPURTENANCES

### 1.1 Preliminary Precautions

The effectiveness of disinfection depends to a large extent upon keeping pipes and appurtenances free of dirt and foreign material during construction. Caked-on material will generally not be removed during flushing operations. Subsequent chlorination then becomes ineffective since chlorine is considered to be a surface contact disinfectant.

Since pipes awaiting installation at the job-site may accumulate debris and dirt these should be visually inspected.

and, if necessary, cleaned prior to lowering into the trench. In some cases the inside of the pipe may have to be swabbed with a strong chlorine solution applied to a mop-head pulled with a cord through the pipe. It may become necessary in some instances to cover both ends of a pipe before lowering it into a trench to ensure that it does not pick up earth from the trench walls. The ends of the pipe should be checked and cleaned before final coupling. If ground water is a problem in the trench, a water tight plug should be inserted in the pipe end immediately. Ground water will carry mud and it may be contaminated by sewage from severed laterals. A plug should also be used in the last laid section of pipe during any unattended period to prevent entry of small animals or foreign material such as gravel, metal fittings, sticks, or packing.

Appurtenances such as valves, meters and corporation cocks should be kept packaged and clean until ready for use. These may be disinfected immediately prior to installation by thoroughly cleaning all surfaces and brushing on a one per-cent chlorine solution. Meter parts should not be overly exposed to strong chlorine solutions.

1.2 Flushing

Flushing of a water main should be carried out only after the pressure tests have been made and the pipeline found acceptable. The pipeline should be thoroughly flushed through hydrants or specially installed taps to develop velocities of at least 2.5 feet per second. Hydrants or flush out valves must be installed at the ends of mains to facilitate flushing of dead-end sections. The following table indicates the size of opening required and the flow involved at 40 psi pressure to ensure the provision of the minimum flushing velocity.

Table No. 1
Required Opening Size for Minimum 2.5 fps Flushing Velocity

| Pipe Diameter (inches) | Flow (gpm) | Opening Size (inches) |
|---|---|---|
| 4 | 100 | 15/16 |
| 6 | 220 | 1 - 3/18 |
| 8 | 390 | 1 - 7/18 |
| 10 | 610 | 2 - 5/16 |
| 12 | 880 | 2 - 13/16 |
| 14 | 1200 | 3 - 1/4 |
| 16 | 1565 | 3 - 5/8 |

It can be seen from Table No. 1 that adequate flushing velocities may not be attainable in mains over 16 inches in diameter. For this reason extra precautions should be taken to ensure that large pipes are absolutely free of dirt and debris during construction.

The procedure for flushing requires that hydrants and special taps be opened in order starting from the feed source and gradually working out towards dead-ends. The interconnecting gate valve controlling flow from the system should be released only after the first hydrant valve has been opened. Flushing must be a continuous operation until completed when the final hydrant and interconnecting gate valves are closed simultaneously. This procedure avoids the possibility of unchlorinated water flowing back into the feed main and carrying contamination into the potable water supply.

1.3 Chlorination

There are several sources of chlorine available and various methods of application for the disinfection of watermains. While gas chlorination is the most economical its application is generally limited to new water works systems. The development of direct-mounted chlorinators, however, could increase the use of gas systems for watermain disinfection in the future. Other types of chlorine include 70 per cent H.T.H. (calcium hypochlorite) powder or tablets, and liquid sodium hypochlorite at 15, 12, and 6 per cents

available chlorine. There are advantages and disadvantages to the use of each.

Powder and tablets are the simplest to use, being deposited in each pipe length. However their use has the disadvantage that the system cannot be thoroughly flushed prior to chlorination, and there is a lack of control on concentration and mixing of the chemical. Many tablet adhesives have been found inadequate to hold the tablets in place during flushing. As a result they are often flushed out or carried to the ends of the lines before dissolving. A further disadvantage is that when water temperatures are below 41°F. the slow dissolving rate of the tablets precludes their use.

Powder may of course be dissolved in solution and injected as a liquid hypochlorite solution manually or through the use of a small positive displacement pump. The latter is more desirable as it provides steady dosing of the water entering the new mains. The preferred point of chlorine application is near the beginning of the main extension through a corporation cock installed in the top of the main. The chlorine dispensing apparatus should be located close to and on the downstream side of the interconnecting gate valve controlling flow into the new mains. The procedure for manipulating valves is similar to that used for flushing. This prevents a back-flow of highly chlorinated water from entering the potable water supply.

The highly chlorinated water must be retained in the mains for a period of at least 24 hours and produce a minimum 10 ppm available chlorine residual at the end of that time. This will generally require a starting residual of at least 50 ppm. This matter is currently under review by a committee of the AWWA which is considering an increased dosage to produce a 25 ppm available chlorine residual after 24 hours. Apparently the relatively small increase in cost for additional chlorine, in some cases, more than offsets cost by delays which result when flushing and chlorination procedures must be repeated because of unsatisfactory disinfection.

The amounts of gaseous, powdered or liquid chlorine required to produce a 50 ppm chlorine dosage may be

calculated for any section of watermain. The following sample calculations are for one mile of 8 inch watermain which will hold 11,500 Imp. gallons (I.G.) of water.

Table No. 2

Chloride Requirement Sample Calculations

A. Chlorine Gas Required (consider 100% effective)

$$50 \text{ ppm} \times 11{,}500 \text{ I.G.} \times \frac{10 \text{ lb.}}{\text{I.G.}} \times \frac{1}{10^6} = 5.75 \text{ lb. gaseous chlorine}$$

B. 70% HTH Required (consider 75% effective)

$$= \frac{5.75 \text{ lb. chlorine}}{0.70 \times 0.75} = 11.0 \text{ lb. of 70\% HTH}$$

C. 15% Sodium Hypochlorite Required (consider 75% effective)

$$= \frac{5.75 \text{ lb. chlorine}}{0.15 \times 0.75} \times \frac{1}{10 \frac{\text{lb.}}{\text{I.G.}}} = 5.12 \text{ I.G. of 15\% Solution}$$

Similar calculations can be carried out for 12 and 6 per cent sodium hypochlorite solutions both of which should be calculated considering only 75 per cent effective available chlorine. The chlorine residual should be checked at each hydrant or special flushing tap and the 50 ppm residual assured prior to closing the valve at that point. For this purpose litmus paper or orthotolidine testing solution may be used. The orthotolidine test will produce a solution with a deep yellow-orange colour. The exact chlorine residual may be determined by diluting the solution with chlorine-free water to a level where a colour comparator can be used. After 24 hours the chlorine residuals should again be determined.

### 1.4 Bacteriological Testing

Following the required retention period the highly chlorinated water shall be completely flushed from the

treated main at its extremities until the replacement water throughout its length has a chlorine residual comparable to the potable water in the supply system. Only then should bacteriological samples be obtained from various outlets along the new main. Should these samples prove to be bacteriologically satisfactory, then the new main may be placed into service. However, in the event that these results are adverse, then the disinfection programme must be repeated until satisfactory results are obtained.

## DISINFECTION OF OTHER EQUIPMENT

### 2.1 Reservoirs and Storage Tanks

As with watermains, reservoirs and storage tanks must be thoroughly cleaned before disinfection is attempted. All dirt, scale, loose paint, and other material must be removed. This may require cleaning down the walls and floor using a steel brush.

Disinfection can be accomplished by spraying a strong 250 ppm chlorine solution on cleaned surfaces from a portable back-pack or other mechanical spray unit. Caution must be exercised in using this method as chlorine fumes are toxic. The reservoir or storage tank should be adequately ventilated before entering, with the worker wearing protective clothing and goggles and utilizing an air mask with a bottled or outside source of air supply. A second worker, with protective mask readily available, should be stationed outside the tank or reservoir within sight of the inside worker in case of emergency.

A second method of disinfection which is satisfactory for small tanks requires the filling of the tank with a 50 ppm chlorine solution. All air must be removed from pressure tanks while filling with chlorine solution to ensure contact of the chlorine with all inside surfaces. As with watermain disinfection, a minimum 10 ppm chlorine residual should be present after a 24 hour retention time. In an unpressurized tank the wall surfaces and ceiling, above the water line, should be flushed with a strong chlorine solution.

Bacteriological samples should be taken only after the disinfecting solution has been fully removed and the chlorine residual in the tank the same as that in the supply system. If bacteriological results are satisfactory then the facility may be placed in operation; if not then the disinfecting procedures must be repeated.

### 2.2 Wells and Equipment

Since most well water is not chlorinated on a routine basis, primary disinfection is very important. All equipment contacting potable water, such as pumps, casings, drop pipes and other well appurtenances, must be thoroughly disinfected prior to being placed in service.

Before installing drop pipe and pump remove all surface mud and debris. When the pump is installed apply a chlorine solution to obtain a 50 ppm chlorine residual in the well. Then operate the pump in order to obtain a strong residual at the end of the newly constructed distribution feed line. Where a long feed line is involved, the chlorine should be added slowly and continuously to the well. The highly chlorinated water should be retained in the well and distribution feed line for a 24 hour period. Where possible some of the heavily chlorinated water should be returned back down the well between the casing and the drop pipe during the first 30 minutes of pumping in order to wash down and disinfect the inside of the casing.

After all disinfection water has been removed from the well and distribution feed line, samples should be obtained for bacteriological analyses. Adverse bacteriological results should be followed by a repeat of the disinfection procedures. Continued adverse results may be attributed to ground water contamination in which case continuous chlorination of the supply will be required.

DISINFECTION OF REPAIRED MAINS AND APPURTENANCES

3.1 Major Repairs and Planned Connections

Leaks and breaks in existing mains may occur at any location in a system. Major repairs and the planned installation of valves and other appurtenances in an old system will require partial or total dewatering of the affected section of watermain. The locations of existing valves and hydrants relative to the repair work will dictate the particular approach to disinfecting that particular section of main.

Whether the old main is opened by accident or design, the excavation is always wet and frequently badly contaminated. Thus the likelihood of serious contamination must always be considered in planning proper disinfection procedures. Because there is always a certain amount of urgency involved in putting an old main back into service, the importance of the service rendered by the main will be a determining factor in establishing the methods of disinfection which are to be followed.

Where sections of old pipe must be replaced or new appurtenances installed, the excavated trench must be kept in a dry condition while installation is underway. Construction precautions should be similar to those employed in the installation of new mains. The interior of each replacement pipe should be swabbed with a strong chlorine solution. Valves, fittings and other appurtenances should be washed with one per cent chlorine solution immediately prior to installation.

Ideally the isolated section of main should be thoroughly flushed and chlorine added to produce a minimum 50 ppm chlorine solution. At least a 10 ppm chlorine residual should be present in the affected section after 24 hours of contact time. Flushing and chlorination through existing hydrants is most convenient but in some cases it may be necessary to install a special flushing tap which may also be used for introducing chlorine. In all cases the chlorine shall be applied in such a way as to ensure that a high concentration reaches every part of the isolated section of

main. Bacteriological testing and resultant acceptance or rejection for service will dictate the need for re-disinfection. Adequate initial chlorination can significantly reduce the chance of inadequate disinfection.

### 3.2 Minor Leaks and Repairs

Many minor leaks may be successfully repaired through the use of clamping devices and repair sleeves. Often the repairs are carried out while the mains continue to supply water under pressure. The leak or break should be fully exposed and cleaned of dirt and other contaminants before repair. In addition, the gasket which comes in contact with the break should be thoroughly disinfected with a strong chlorine solution immediately before it is clamped to the main. Following completion of repairs the system in the vicinity of the leak should be sampled for bacteriological contaminants. A clean repair job is essential for keeping contamination out of the system.

## DISINFECTION FOR SYSTEM PROBLEMS

### 4.1 Types of Problems

Disinfection of a water system or operating equipment is required when adverse bacteriological tests show the presence of coliform bacteria, the usual indicator of contamination. This may be the result of water system construction or repair activities. On the other hand disinfection may be necessitated to combat colour, taste and odour problems which develop due to the presence of nuisance organisms in the system; such are the iron bacteria and sulphur reducing bacteria. By maintaining a chlorine residual in the distribution system these non-pathogenic slime-forming organisms can be controlled.

The common iron bacteria, <u>Gallionella</u>, <u>Leptothrix</u> and <u>Crenothrix</u> are pipeline growths which derive their energy from the oxidation of ferrous iron. The resultant growth is a mesh of threads encased in a slimy sheath which traps and holds insoluble oxidized iron as well as other organic and inorganic solids. It is interesting to note that

the growth of *Gallionella* is favoured in cold waters while *Leptothrix* and *Crenothrix* thrive in warmer waters. Sudden flow reversals or velocity changes in the mains can disturb settled iron precipitate and break loose varying quantities of iron bacteria for discharge. While "red water" conditions are not necessarily accompanied by the presence of iron bacteria their existence may intensify the colour and taste problems.

In oxygen depleted water, many of the lower bacteria are capable of reducing sulphur to the odourous hydrogen sulphide. One particular species grows best in warm, sulphate-bearing waters and might be found in abundance in dead-end mains and in the bottom of hot water tanks. Where sulphides are formed a black sediment and offensive odours are very evident.

Where colour, taste and odour problems, of the types related to iron and sulphur, are found in a system then samples should be examined under laboratory conditions for the presence of iron and sulphur reducing bacteria. It should be stressed that disinfection is intended to rid the system of these nuisance organisms and not to remove iron from the water supply. The use of disinfection to control these bacteria is governed by the necessity for maintaining a high enough chlorine residual to reach the infected area while, at the same time, not causing serious chlorine taste problems. To be effective, chlorination must be accompanied by an adequate flushing programme.

## 4.2 Disinfection of Small Chlorinated Systems

Where a water works system is equipped with chlorination facilities at the source, the distribution system or other appurtenances can be disinfected by increasing the chlorine residual leaving this source. The primary residual is raised to, say 0.5 ppm, and hydrant flushing is carried out to obtain some residual in the infected area. The disinfection programme can be carried out for a few weeks or as bacteriological results indicate. Flushing may have to be repeated a number of times to maintain a residual in the infected area. It is noted that even trace residuals over a long period of time will be effective.

In urgent cases, such as where serious coliform contamination is encountered, higher chlorine residuals may be warranted.

### 4.3 Disinfection of Large Chlorinated Supplies

In large distribution systems it may be difficult to maintain even a trace chlorine residual without having a very high residual at the source, and/or wasting excessive quantities of flushing water. The creation of a chloramine residual is sometimes a solution. The addition of one part ammonia to three parts chlorine will create this residual which will last longer than a free chlorine residual. However, the disinfecting power of this combined residual is greatly reduced over that of a free chlorine residual. Therefore, this change should not be made without careful consideration as to its effect on the bacteriological quality of the treated water.

When first attempting to blanket a large distribution system with a chlorine residual, taste problems may develop. Also, difficulty may be encountered in blanketing the system with even a chloramine residual. At first the oxidation and destruction of organic matter and various infestations will use up the applied higher residual, but after a time the taste problem should stop and the residual advance to the required areas. The end result will of course be a much cleaner distribution system.

### 4.4 Disinfection of Unchlorinated Supplies

When a water works system is not equipped with permanent chlorination facilities, a temporary method must be devised for injecting the chlorine into the infected parts. Batch addition of a chlorine solution or the installation of a chlorinator will be required. Generally the batch addition of chlorine solution is not to be recommended. Where a storage well is available, such as a spring reservoir, a simple drip arrangement may be devised for obtaining the necessary residual. Again the chlorine residual may be maintained at say 0.5 ppm at the nearest consumer. Frequent flushing may again be needed to maintain the required residual in the infected area.

The disinfection of a distribution system serving an unchlorinated well supply may require the installation of a hypochlorinator or gas chlorinator on a temporary or permanent basis.

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# Maintenance of Steel Storage Tanks

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## INTRODUCTION

The maintenance of steel storage tanks consists of regular inspection and preventative measures, such as the use of protective coatings and/or cathodic protection. This paper discusses the operation, inspection, the corrosion of and the preventative maintenance for steel storage tanks.

Since our Company is involved in the design, manufacture and inspection of steel water tanks, we are often asked the question "what is the life expectancy"? Our answer is, we do not know, we have only been in business 57 years. Many of our first riveted tanks have been in continuous service for over 50 years and so it would be reasonable to expect a modern tank to last considerably longer provided the tank is properly maintained.

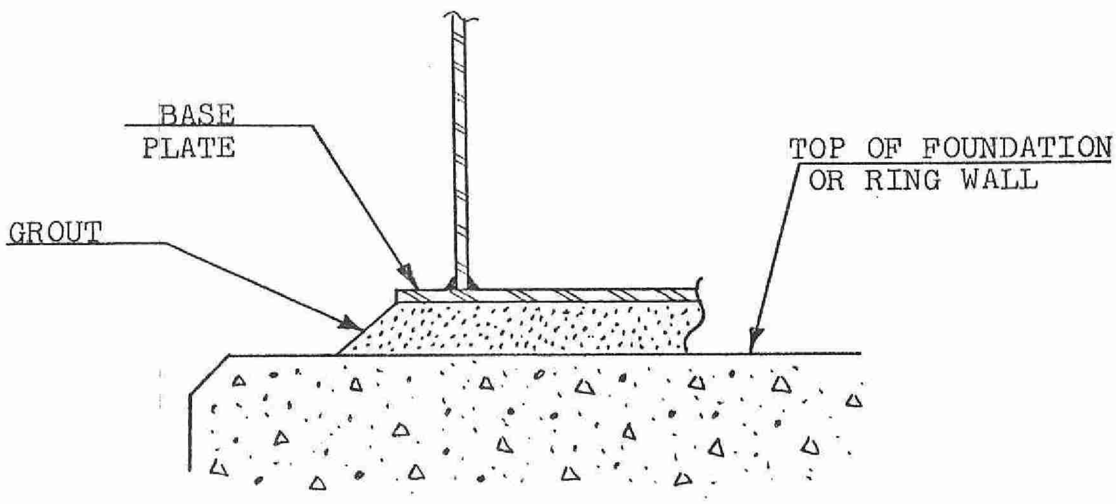
Unfortunately, many tanks are only maintained on the outside mainly because of appearance, while the interior surfaces are often ignored due to a reluctance of personnel to climb and the inconvenience of taking the tank out of service. As an example, I recently examined a reservoir which had not been opened since the day it was built and the tank was 20 years old.

Regular inspection is the first consideration of any maintenance program. The main purpose of the inspection is first to detect and correct any problem that may develop into a hazard and second to detect any significant deterioration and to correct it through minor repairs. Inspection can often be made by qualified water utility personnel. However, it is desirable to have a check list of things to examine and the list will vary depending upon the style of the tank. AWWA Standard D 101-53, "Inspecting and Repairing Steel Tanks, Standpipes, Reservoirs and Elevated Tanks for Water Storage" is a good guide although it is essentially set up for the older style riveted elevated tank.

We would suggest that periodic inspection be made by waterworks personnel at least once a year. In addition, it is suggested that all tanks be inspected regularly at intervals of not more than 5 years by experienced people. Most manufacturers will provide this service and even if they do not, they probably can suggest competent talent. Also, there are inspection agencies and engineering firms willing to handle inspections.

Accurate and complete records of all inspections and maintenance work should be kept. These records should be readily available so that a quick review can be made from year to year to determine if any deterioration has taken place. This would seem like a basic requirement but time after time, we ask the question "when was your tank last repaired" to receive the reply, "we think it was something like 12 years ago".

Before examining the tank proper, look for signs of differential foundation settlement. This applies to the column and riser piers of elevated tanks and the ring wall of water reservoirs and single column tanks. Differential settlement of the foundation is very rare and usually can only occur if the soil has been seriously eroded by some external source such as an excavation or a washout. However, it is quite common to find the grout between the foundation and the tank in poor condition.




This grout is designed to transfer a uniform bearing pressure from the tank to the foundation and its deterioration can cause cracking of the concrete or differential settlement.

Broken, chipped or spalling grout should be repaired.

If the exterior surface has been subject to prolonged exposure without paint, serious corrosion can occur. This is especially true in chemical atmospheres containing hydrogen sulphide or sulphur dioxide or marine atmospheres containing salt. The corrosion problems can also be more evident in older riveted tanks which have many more laps, hidden surfaces and edges which are difficult to clean and paint properly.

Corrosion on the interior surfaces is usually more serious than the exterior since the environment is much more severe. Interior corrosion is generally characterized by the zone in which it occurs. Figure No. 1 shows the usual three zones: Vapour Zone, Fluctuation Zone and the Submerged Zone.

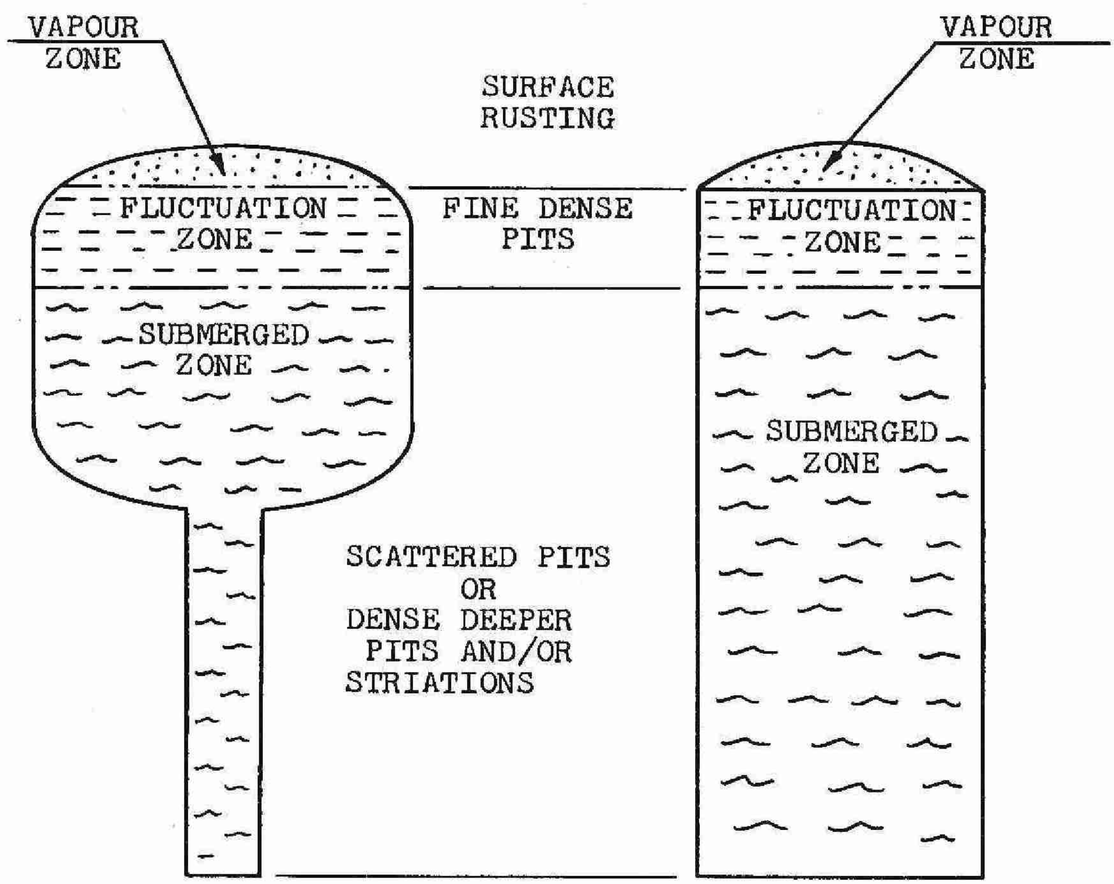



FIG. NO. 1

## VAPOUR ZONE

Corrosion in this zone is usually not serious except in the older tanks where structural details make it difficult to apply a suitable protective coating. Any rusting is usually in the form of surface rusting only.

## FLUCTUATION ZONE

Pitting can occur in this zone but it is generally neither deep nor too extensive. The corrosion is more likely to be uniform with any pitting being fine and dense. A heavy build-up of rust scale may also occur. This does not imply that prolonged corrosion in this zone cannot become serious especially if the water level remains level for long periods of time.

## IMMERSED ZONE

Corrosion of the immersed surfaces is usually in the form of pitting. The pitting may be scattered and few, uniform and dense or in the form of vertical grooves and called striations.

Scattered pitting usually appears where a small bit of paint has been either damaged or failed but is surrounded by areas of good paint.

Dense pitting is common where there is relatively large areas with little or no paint or other means of protection. This can become serious especially if the dense pits develop into the vertical groove type of pitting which can weaken the structure.

An actively corroding pit or striation is usually covered by a bright red-orange rust nodule which projects above the surface of the parent metal. The rust nodule is soft and when wet, can be easily removed with your finger. The metal under the pit is shiny and bright. The pit can also be covered by a black rust nodule or tubercule again extending above the surrounding surface. This may be slightly harder to remove but underneath the same shiny metal is evident.

When examining a tank and pitting is found, one should record the location of the pits, the density (number per sq. ft.), the diameter and the depth.

The outside of steel tanks usually should require no more than local patch priming and one complete coat at regular intervals. Unless it is desired to paint sooner for appearance, the time to apply a complete new finish coat is when the top coat has eroded to the extent that the underlying coat starts to show through and well before rusting occurs.

The successful protection of immersed surfaces depends on the maintenance of a continuous film to prevent rust formation. The existing paint film should not be allowed to deteriorate so badly that rust occurs beneath it. Rust development to any appreciable extent means extensive cleaning to bare metal and such procedures are costly and time consuming. Further, unless thorough cleaning methods are taken to restore the surface of badly corroded steel to good condition, any protective coating system will have a shortened life

The greatest cost savings in maintaining submerged surfaces can be gained by repainting at the right time. This means frequent inspection and the undertaking of the necessary maintenance painting immediately as it becomes necessary. Inspection will indicate serious signs of failure, such as, severe blistering, rusting, cracking or peeling. The crucial symptom of failure of a coating is rusting and repainting should not be delayed beyond its appearance on more than 1 to 2% of the surface. Unless painting is done at this time, the cost of repairing rapidly becomes greater until the point is reached where it is cheaper to blast clean the whole structure and start fresh with a completely new system.

There are a number of items readily handled by waterworks personnel that will help ensure trouble free operation. Most municipal tanks are unheated although some of the smaller tanks in the colder climates are heated. If your tank is equipped with a boiler,make sure it is working properly before the onset of freezing weather.

An unheated tank is subject to freezing in the form of ice buildup on the inside of the tank walls, on elevated tank bottoms and centre risers. Also, an ice cap will form across the top of the tank. This ice formation can tear out inside ladders, inside overflow piping, cathodic protection anodes and their accessories. This is why many of these items are now eliminated in Canadian tanks whereas they would cause no concern in warmer climates. The ice cap can also cause problems if it become sufficiently thick that it seals the tank thereby causing a vacuum during water withdraw which could pull in the tank wall.

A municipality with a potential freezing problem can often arrange a schedule so that the water level is drawn down during the day and the pumps operated to fill the tank at night. The procedure adds heat to the tank since the incoming water is usually well above freezing. The fluctuation of the water level also helps break the ice cap thereby keeping it relatively weak.

As an example, a 250,000 gal. uninsulated steel elevated tank subjected to an outside temperature of -10 deg. F., can lose heat at a rate of 950,000 B.T.U.'s per hour.

Assuming a well water supply at 38 deg. F., 510,000 gals./day would be required to maintain the interior at above 32 deg. F. If some ice buildup were allowed (say 6" on the walls) then approximately 238,000 gals./day would be required. In other words, as a rough guide, a water volume at least equal to the capacity of the tank should be circulated each day in very cold weather.

Problems can also arise from an overflowing tank in cold weather. Overflow from a stub type overflow, can cause ice buildup on the tank which can present structural problems. Also, just a dribble of water through an overflow can cause a gradual buildup of ice which can freeze the pipe solid and a solidly filled overflow can rupture especially if it runs to the ground. In addition, a frozen overflow can add pressure to the underside of the roof and this could result in structural damage.

Always check the level controls in the Fall, to ensure the tank will not overflow. Often it is wise to operate the tank at a slightly lower level during the Winter to eliminate any possibility of water overflowing.

There are certain health aspects to be considered in connection with the operation and maintenance of reservoirs and elevated tanks. One of the most obvious, is to maintain the tank in a tight condition with all openings such as vents, overflows, and roof doors protected to prevent access by birds. It is not uncommon to find dead birds in a tank during an inspection. Under no circumstances should fine mesh screens be used on vents or overflows, as these are suseptible to clogging, by freezing vapour.

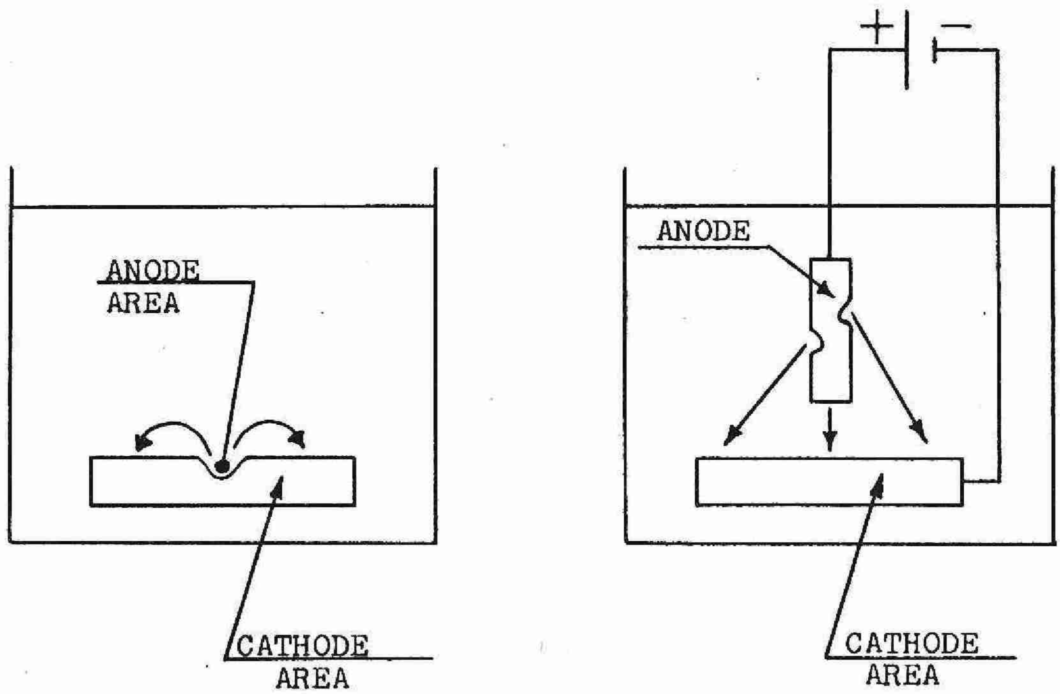
Most tanks are equipped with a washout or drain flush with the tank bottom or tank riser. This washout should be operated periodically until the water runs clear. This prevents a buildup of sediment from entering the tank inlet.

Practically all corrosion of steel occurring at normal temperatures is electrochemical in nature. For example, if two metals, say copper and steel are joined together and immersed in water, a voltage is set up between the two and an electrical current will flow. With the iron and steel combination, the current will flow through the steel (called the anode), into the water (called the electrolyte) out of the water into the copper (called the cathode) then back to the steel to complete the circuit. The steel will waste away and the copper will remain unchanged. You will have probably seen this, where someone has joined a steel water pipe to a copper water pipe.

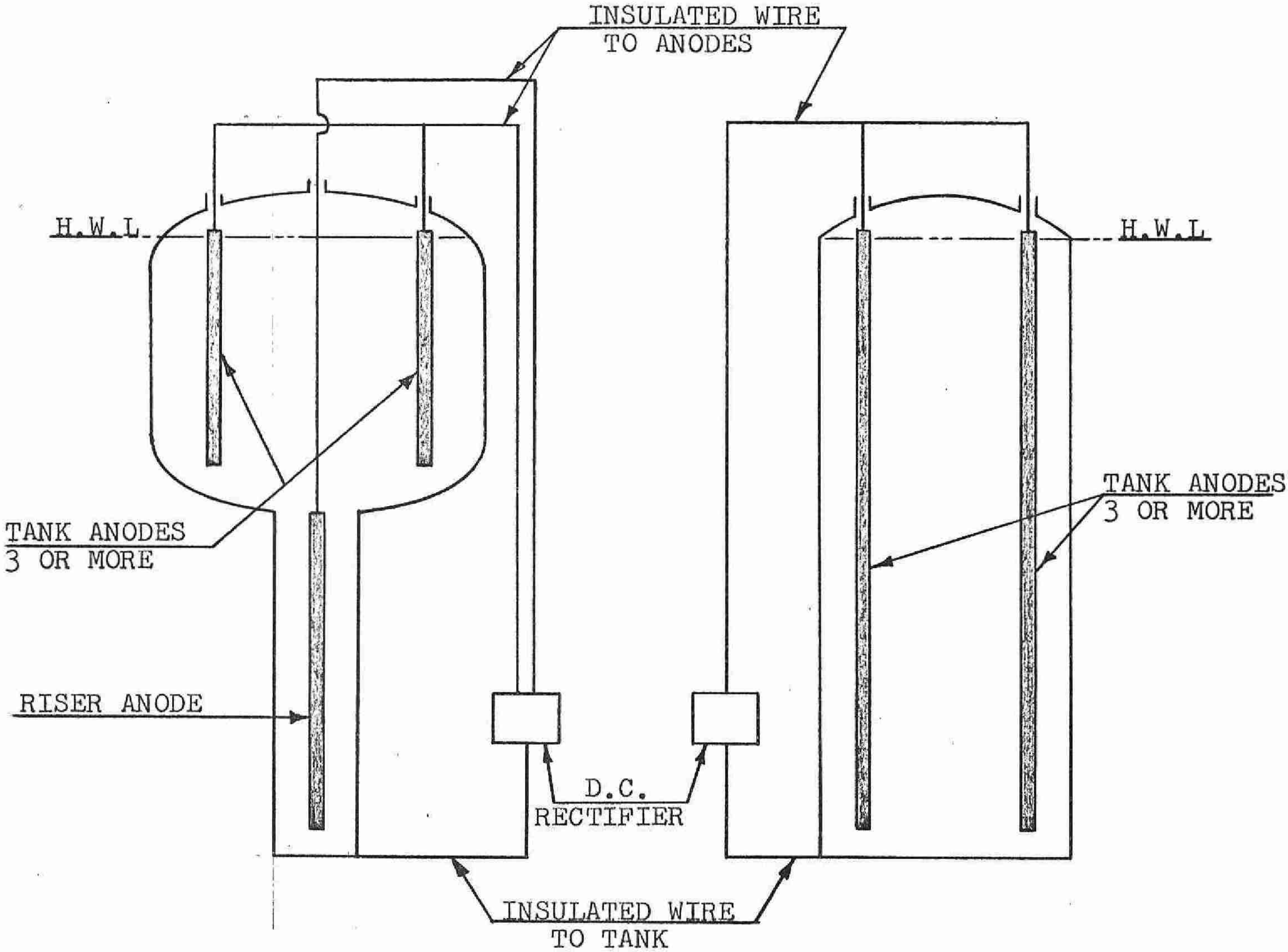
It is not necessary that the cathode and anode be of different materials. If the amount of oxygen dissolved at the anode is different from that dissolved at the cathode a current will be generated even though the anode and cathode are of the same material.

There are many more combinations, but the important thing to remember is where the electric current leaves the metal surface, corrosion will occur and where the current enters the metal, the metal remains unchanged.

Cathodic protection is a method sometimes used to protect steel. Since corrosion does not take place at the cathodic areas, all one has to do, is keep the entire structure cathodic. To do this, we need separate anodes located so that a current from the anodes will flow to all parts of the structure and make them cathodic. The anodic areas of the structure will be overwhelmed by the larger current coming from the anodes so they too become cathodic.




Cathodic protection is sometimes used to protect the submerged surfaces of steel water tanks. Again, this works by making all submerged surfaces cathodic.




TYPICAL CATHODIC PROTECTION INSTALLATION

Unfortunately I have personally found very few Cathodic Systems used in municipal tanks to be working properly. The reasons for the poor operation are varied but generally we find the following:-

1. The anodes are either not installed, they are not installed properly or they are lying on the tank bottom.

2. Poor anode arrangement is poor or there is insufficient rectifier current or rectifier capacity.

The anode arrangement is designed to provide a more or less uniform current distribution over the entire surface. With poor anode placement or too few anodes this can not be achieved. The current required is a function of the tank area, the resistivity of the water and the overall circuit resistance of the system. Therefore an inadequate power setting or insufficient rectifier capacity will also allow corrosion to occur.

It should be remembered that you cannot tell from the rectifier reading alone, whether or not the tank is being adequately protected. Proper rectifier settings can only be determined by using a reference electrode and taking a solution potential survey. Once the proper current level is established, it can be maintained without the need of a new survey providing conditions within the tank do not change drastically.

Aluminum is the most common anode material for municipal tanks. The anodes are usually designed to last one year and are replaced each spring after the danger of ice buildup is passed.

Only by being immersed in water (electrolyte) can the tank surfaces be made cathodic. This means the underside of the roof (vapour zone) and the fluctuation zone will require a protective coating.

Cathodic protection is a specialized field. We would strongly suggest if your tank is equipped with this system that you hire a firm specializing in this work. They can perform the necessary surveys, adjust your rectifier and otherwise provide the year to year maintenance.

The most common corrosion prevention method is the use of protective coatings. Since most corrosion is electrochemical, inserting an insulating barrier between the anode and cathode the flow of current is suppressed and the corrosion halted.

In reality corrosion is retarded by paint in a number of other ways. One way, is through the formation of a mechanical barrier on the surface of the steel which keeps out moisture and oxygen. Unfortunately, no paint is completely impermeable and even the best will eventually fail by allowing passage of these agents. When a paint acts as a mechanical barrier only, it must be very impermeable or very thick.

Good adhesion of the paint to the steel is essential. Barrier type coatings must have good adhesion otherwise the moisture and oxygen penetrating the films will displace the coating from the surface and rusting will result.

The first coat of paint (primer) on a steel surface in addition to having good adhesion and resistance to the passage of corrosive agents must have rust inhibiting pigments. If a film becomes damaged these pigments tend to be soluable in water and will leach out of the paint film. By so doing, they will stifle any corrosion for a short period of time.

Another type of protection is available with the so-called sacrifical pigments such as the zinc rich paints. These have such a high concentration of zinc that they act much the same as galvanizing.

In summary, a suitable metal protective paint should have rust inhibiting properties, low permeability, low water absorption, high dialectric strength and good adhesion. All these properties are not absolutely essential, if not impossible to achieve in any one coating. However, most successful coatings contain a majority of these properties.

At least 1/2 of the life of any paint system is determined by surface preparation. Paint should be applied to clean dry metal free of oil, grease, rust and mill scale. Mill Scale is cathodic to steel so its removal is essential especially in immersed surfaces or corrosive atmospheres, Rust tends to absorb moisture from the atmosphere thus further increasing electrochemical corrosion. However it is possible to paint over slight rust residues or mill scale and if the atmospheric exposure is not too severe provided a good wetting rust inhibiting primer is used.

In repainting interior surfaces it must be stressed that good surface preparation is absolutely essential otherwise, the paint will fail. We would suggest that the minimum degree of cleaning consist of at least a blast clean to a "Commercial" grade with a "Near White" grade being the preferred. Again, the extent of surface preparation will depend on the condition of the existing paint.

A discussion on types of protective coating is beyond the scope of this paper. AWWA Standard D 102-64,"Painting and Repainting Steel Tanks, Standpipes, Reservoirs and Elevated Tanks for Water Storage" may be of some value. As a further reference, I would suggest the Steel Structures Painting Manual, Volume 1, GOOD PAINTING PRACTICE and Volume 2, SYSTEMS & SPECIFICATIONS. Both manuals are available from the Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburg 13, Pa., U.S.A. In addition, many paint manufacturers have proprietary paint systems suitable for both exterior and interior service.

Regardless of the paint system used it is wise to evaluate by using the basic principles namely the dialectric strength, the permeability, the adhesion and the rust inhibiting ability. Again, we emphasize the need for good surface preparation. Priming coat should have a minimum film thickness of from 1 1/2 to 2 mils and intermediate and finish coats should have a minimum thickness of 1 to 1 1/2 mils/coat. Minimum overall dry film thickness should never be less than 4 mils. (one mil is .001 inches).

Application is second in importance to surface preparation in determining the service life of a paint system. Most paints should be applied in dry weather with a relative humidity not higher than 85% and a temperature not lower than 40 deg. F. Painting should not take place if rain is imminent nor if there is danger of freezing before the paint is dry.

To repeat the most economical life out of a paint system it is desirable to maintain the film by frequent spot cleaning and repainting. If local breakdown occurs the spot cleaning reduces the spread of rust and maintains the appearance of low cost. Once the underlying metal is stabalized, no further rusting or breakdown of the film occurs except for perhaps gradual erosion of the outer coat. Therefore, when it is apparent the outer coat of paint is wearing thin, then it is time to add one additional coat of paint.

There is no reason for a steel tank to ever require replacement other than the fact that it may become obsolete. Certainly structural integrety can be maintained indefinitely provided you have a program of preventative maintenance. If you have a steel tank, examine it yourself or have it examined by experts. Learn to recognize signs of corrosion, analyse the cause and then take the proper remedial action. A small amount of money spent wisely on preventative maintenance can prevent the necessity of major repairs sometime in the future.

# "FLUSHING AND SWABBING OF THE DISTRIBUTION SYSTEM"

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## INTRODUCTION

This paper will consider the problems associated with the flushing and cleaning of water mains in the distribution system, with special emphasis on the use of foam swabs. The methods and techniques discussed will be quite general and, we feel, adaptable to most water distribution systems.

## DEFINITION

Flushing and swabbing water mains is a means of removing encrustations, debris, rust, and other foreign objects from a distribution system to alleviate consumer complaints or to restore the carrying capacity of the water mains.

## FLUSHING PRACTICES

When a consumer complaint is received, regarding discoloured water or taste or odor in a particular area of the distribution system, we are faced with the problem of rectifying the situation. What caused the problem? Was it due to the use of a fire hydrant for flushing or for fighting a fire? Could it be caused by an unusually high flow in that area of the system? If the customer has had the problem reoccur, the situation becomes even more undesirable.

In any event, the normal procedure is to dispatch a work crew and flush the main through a hydrant or other blow-off. However, unless exceptionally high flows can be maintained, the amount of debris removed will be minor. The table below indicates minimum flows, for various sized mains which will be effective for main flushing.

| Pipe Diameter | Minimum Effective Flow from Hydrant |
|---|---|
| 3 inch | 95 G.P.M. |
| 4 inch | 200 G.P.M. |
| 6 inch | 540 G.P.M. |

We must also consider the effect of flushing on the rest of the distribution grid. Very often, we merely compound the problems in other areas by redistribiting the debris in the mains. We have all had the experience of flushing a main and noting the large amount of rust removed in the first few minutes. The water then clears up rapidly and we shut down only to have the problem reoccur within another month or so. Many man hours are used up in this procedure but, unless a planned program of flushing and swabbing is maintained, the benefits are doubtful.

## SWAB MATERIAL

Swabs are made of polyurethane foam which has compressibility, tensile strength, and the required density. Two grades are generally used:- AOP35-soft and AOP22-hard. The swabs are cut into cylinders and the length is at least one and a half times the diameter. This latter sizing is to prevent the foam swab from tumbling over as it enters the main, therby ensuring that it passes through the main as a cylinder. The following table lists suggested sizes for foam swabs.

| Pipe Diameter | Swab Diameter | Swab Length |
|---|---|---|
| 1½ inches | 2 inches | 4 inches |
| 2 inches | 2½ inches | 5 inches |
| 4 inches | 5 inches | 10 inches |
| 6 inches | 8 inches | 12 inches |
| 8 inches | 10 inches | 15 inches |
| 10 inches | 13 inches | 19 inches |
| 12 inches | 15 inches | 22 inches |

It should be noted that for first runs, the AOP35 is generally used because it will tear easily and will not be easily held by any obstruction.

## BASIC METHOD

In this method, the polyurethane foam swabs are placed into the mains and are propelled by the pressure differential in the main to the downstream egress of the main. Normally, on 6 inch mains, hydrants will be used to introduce and remove the swabs. It will be necessary to dismantle the hydrants by removing the spindle, rod and seat assembly. Since the swabs are compressible and pliable, they may be squeezed through the hydrant hose connections, into the body of the hydrant. Numerous tests in our Distribution Yard have indicated that, irregardless of how the swab was pushed into the hydrant, it assumed the cylindrical position when the water pressure was applied.

If swabs are to be introduced from a hydrant into the mains, water pressure must be applied to the hydrant to force the swab through the hydrant and its connections. It is essential, of course, that all valves in the system to be swabbed are closed and that only the control valves shall be operated. It would be most distressing to have the swab negotiate an unexpected "Tee" and be lost in the system.

In order to effectively clean the main, velocities in the range of 4 feet per second should be used. Velocities in excess of this cause the swab to "slip" by material in the main, resulting in an inadequate job. The mains must be full of water, when swabbing, and a net or bag should be used to collect debris and particles of swab from the main. Before you start the proceedure, WARN your customers. Public relations could be strained severely if the customers happen to use water from the main just prior to or after the swab has passed their services.

For mains larger that 6 inches in diameter, it will be necessary to use excavation and pipe cutting in order to facilitate the entry of the swab into the main. It may be possible to place the swab into larger mains by removing the works of an "in-line" valve and using this as a point of entry. Mains in excess of 24 inches in diameter have been flushed by the foam swab method.

METHOD IN DETAIL

After selecting the particular main to be swabbed, it is essential that all valves, crosses and tees be located so that a complete present history of the main and its length is recorded. If possible a trial run should be conducted, duplicating all steps in the process to be used. Better to find the problems before inserting the foam swab into the system. It is not necessary to shut off customer services but all customers should be made knowledgeable of what is to occur. In all likelyhood, they will be overjoyed that you are going to do something for them.

If fire hydrants are to be used as an entrance and egress, all working parts must be removed. A solid plate should be installed in place of the hydrant head and some type of cover installed over the drain holes to prevent flooding the ground around the hydrant. If possible, a pressure guage should be installed on the hydrant used for entrance in order to control pressures in the main. A supply of water under pressure must be available to force the swab down through the hydrant and into the main.

For a first run, use an AOP35 foam swab in the system. After the results are assessed it may be desireable to use the same swab for a second run or to use a AOP22 in its place. It should be noted that swabs may be introduced in tandem to conserve down time of a particular main. With experience, the length of main that 'can be swabbed" and the results expected can be predicted. Since the foam swabs are compressible and pliable they will negotiate bends, tees, and valves with no difficulty. A flow test should be conducted on the main before the swabbing commences.

Now insert the swab into the hydrant with all valves except the hydrant valves on hydrants to be used in the closed position. Ensure that the discharge hydrant is fully open and that the collecting net or bag is placed over the discharge opening. Connect the pressure hose to the inlet hydrant and slowly open the valve controlling pressure hose. Pressure in the hydrant will build up for a few seconds until the swab is forced into the main then it will drop to the controlled pressure desired.

Remember that the swabs are porous and that water will pass through them. This prevents a build up of debris in front of the swab which could prevent the proper cleaning action. The water flowing from the discharge hydrant will be clear in appearance when the pressure valve is opened. As the swab approaches the discharge opening the water will gradually become murky and then become quite discoloured. Just prior to the exiting of the swab the water will be a deep chocolate colour and particles will appear in the collecting bag.

After the swab exits from the hydrant discharge, the water flow whould be increased to remove the dislodged material from the main. Depending on the condition of the main, the swab may be virtually intact or for, all practical purposes, completely useless due to extreme tearing. Continue flushing until no further evidence of any dislodged material is apparent. As a further precaution, check the contents of the net to ensure that all parts of the foam swab are accounted for. Now conduct another flow test on the main to ascertain whether further swabbing will be necessary.

After the initial swabbing, it may be adventageous to pass an AOP22 foam swab through the main to remove material of a more stubborn nature. Since this swab exhibits greater tensile strength it may be badly dismembered by this material. Several passes using the AOP22 swab may be necessary but they appear to be more 'effective' in removing hardened tubercles.

SOME OTHER APPLICATIONS

One area in which the foam swabs can be most useful is their application to new mains. Prior to chlorination of new mains, a foam swab AOP22 should be passed through the main. This will remove debris, lumber, paper, bags and other objects which have been left in the main. At the same time, it will remove any silt or mud which has been left in the main. This will reduce flushing times and also ensure that the chlorination of the main can be effective. It may be advantageous to chlorinate the main behind the swab thereby ensuring slow additions of the chlorine and assuredly complete contact with the walls of the pipe.

Another application of the procedure could be in surveying the condition of distribution grids for organisms of a biological nature. Algae, crenothrix, actinomycetes, and other taste and odor or nuisance organisms may be ascertained through spot checking areas in the grid system, where routine flushing may not be advantageous. Once a main is layed in the ground, we very seldom ever remove it for any type of inspection.

We all have the problem of main breaks in our system. How many chlorinate the main after a break? Normal procedure is to apply some bleach to the ends of the break and connect up the pipe, depending on the flushing to remove any contamination. Perhaps the application of foam swabs would be a desireable feature after a main break to ensure complete disinfection of the break area.

CONCLUSIONS:

1. Foam swabs, due to their physical nature, are extremely effective agents to aid in flushing mains.

2. They are relatively inexpensive and the procedure is not difficult.

3. A planned program of flushing and swabbing can prevent customer complaints.

4. Foam swabbing prior to disinfection of new mains can eliminate construction material from the system.

# CONTROL OF NUISANCE BACTERIA

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## INTRODUCTION

In a previous talk we dealt with distribution system housecleaning, namely foam swabbing and flushing of mains. In a very large percentage of cases the need for this treatment is generated by the presence of a group of organisms lumped together under the heading Nuisance Bacteria.

Generally speaking, properly developed deep wells produce reasonably good quality water with a pleasant taste and no distinct odour. Some areas produce water which is salty, high in iron, extremely hard or containing methane (an explosive gas) or hydrogen sulphide (a gas with the characteristic smell of rotten eggs). With the exception of salty (or brackish) water all the others just mentioned require pretreatment of some sort. About all you can do with salty water is cook vegetables.

Assuming the water is pumped from the ground as a clear, colourless pleasant tasting and smelling liquid, one would expect it to come out of the faucets in consumers' homes unchanged. This is generally the case; however, in all too many municipalities the water arrives with a colour varying from yellow to black or smelling anywhere from faintly musty or swampy to foul. In almost all of these cases the root of the problem is one or more varieties of nuisance bacteria. We will now briefly look at these bacteria from the standpoint of their origin, the harm they do, how they behave, and methods of control.

There are three divisions or kingdoms of living creatures - animal, plant and protist. Insects form the largest group in the animal kingdom, seed-bearing plants in the plant kingdom, and bacteria in the protist kingdom.

Most bacteria are single cell creatures which reproduce by binary fission i.e. they split in two. There are three common shapes - cocci which are spherical or nearly so, rods which look like weiners and spirilla which look like corkscrews. Some bacteria are mobile and swim with the aid of flagella (small appendages like hairs). Others form capsules of organic material and exiat in vast colonies which appear as slime. Some bacteria, when they reproduce, remain attached to each other and form chains or geometrical shapes. Virtually all bacteria are microscopic, most of them becoming visible only at quite high magnifications.

Bacteria were almost certainly among the first life forms on earth, and primarily due to their ability to reproduce at great rates, they are extremely adaptable to a change in environment. Thus bacteria are found in boiling hotsprings, glaciers, vacuum packed food and pressurized food. Generally all they require to exist is food in the forms of nitrogen and phosphorus usually (as compounds), and oxygen or a substitute. Thus some bacteria can thrive in oxygen or in the absence of oxygen while others can only thrive in the absence of oxygen. Some bacteria, which normally reproduce by splitting, under adverse living conditions such as lack of food, produce spores which can exist almost indefinitely. This is not a means of multiplying as in a mushroom or puffball but rather a means of survival. One bacterium produces one spore which under suitable conditions will at a later date produce one bacterium.

DEFINITION

Nuisance Bacteria designates a group of bacteria found in water supplies whose only common denominator is that they cause trouble. On the other hand, pathogenic bacteria all have the potential to cause sickness. From this viewpoint one might argue that pathogenic bacteria are a nuisance which is quite true. However none of the nuisance bacteria which concern us are pathogenic.

There are four groups of bacteria which can be categorized as causing a nuisance. These are iron bacteria, sulphate reducing bacteria, sulphur bacteria and a species of the family arthrobacter.

EXPLANATION OF THE PROBLEM

The iron bacteria are probably the most common. They consist of rod-shaped individuals attached end to end and enclosed in a gelatinous sheath to form a filament. These bacteria absorb iron from the water and bind it into the gelatinous sheath to form what looks like a rusty slime. They can obtain iron from the piping due to the corrosive action of the water on the pipe. They prefer still or slow-moving water and must have oxygen. If food is abundant they multiply fastest in warm water (toilet tanks). Generally they seldom produce odours but are responsible for "redwater".

Sulphur bacteria occur only in well waters containing hydrogen sulphide which they can reduce to elemental sulphur. In the process they produce a colourless slime containing the granular sulphur. From an operator's standpoint, the real nuisance is the smell of the hydrogen sulphide in the raw water and a little colourless slime only adds to his woes.

Arthrobacter is the name of a group of bacteria which seem to occur only in some parts of the United States; at least there is no record of them occurring in Ontario. This bacteria exhibits all of the traits of iron bacteria (i.e. redwater, taste and odour) yet they occur in waters whose iron level is apparently too low to support any quantity of iron bacteria.

Sulphate-reducing bacteria are, next to iron bacteria, the biggest headache of water plant operators in the province. This organism is free-swimming in the shape of a short, bent rod. Several joined end to end form a spiral. They multiply in slow-moving or still water and they operate in three distinct ways to cause trouble. In some parts of Ontario the waters are very hard and contain large quantities of sulphate. In these waters the bacteria produce hydrogen sulphide from the sulphate. The hydrogen sulphide is quite acid and rapidly corrodes iron piping producing the characteristic "blackwater" condition.

Where a distribution system is heavily infected with iron bacteria, sulphate-reducing bacteria can obtain their sulphur from the organic matter generated by large, slime growths of iron bacteria, particularly at the dead end

of a main. Thus when flushing a main it is common to get first a slug of blackwater with its attendant rotten-egg odour (from the sulphate reducing bacteria) then redwater from the iron bacteria and finally clear water. Under these conditions no great quantity of sulphate is necessary to support the growth of the bacteria.

The third situation puzzles many plant operators mainly because the solution to the problem hints of witchcraft. Periodically, utilities get complaints of odours found only in the hot water and not in the cold. These complaints can originate from an area such as a subdivision or from individual homes throughout a municipality. Water analysis usually shows low sulphates, low iron and generally no problem with nuisance bacteria. Sulphate reducing bacteria are capable of using gaseous hydrogen in conjunction with small amounts of sulphate to produce hydrogen sulphide. The lower section of a hot water tank provides the ideal environment to incubate these bacteria.

The temperature is approximately 110-120$^{o}$ F and there is virtually no oxygen present since heating of the water drives off this gas very easily. The glass lining of a water tank is not the wonderful protection it is advertised to be. In the lining process, tiny pinholes form which expose the steel tank to the water. During installation any careless plumber can cause the lining to craze and crack away around the fittings either by tightening the pipe connections too much thus, flexing the tank wall, or by soldering directly to an adapter on the fitting and causing uneven heating of the tank wall. As soon as the metal is exposed, the magnesium anode bar begins to dissolved evolving hydrogen gas. The bacteria thus have the last ingredient for prolific growth and the tank begins to smell. A sample drawn from the bottom of the tank generally shows the characteristic "blackwater". The temporary cure is to remove the anode bar; of course the tank rapidly corrodes at the pinholes and/or around the inlet and outlet fittings and must be replaced prematurely, but the smell ceases. It is not very obvious to the customer how the removal of a bar of metal from his hot water tank is going to stop the smell. A similar set of conditions can occur in houses with carefully installed brand new tanks, the only additional requirement is a household water softener. Few people realize that soft water is extremely corrosive to

many metals. Thus the anode bar dissolves even though the walls of the water tank are in good condition. Again the cure is to remove the anode. The life of the tank will probably be about five years. A stone-lined tank has a more impervious coating (no pinholes) and if carefully connected will last many years. Since it has no anode there is no hydrogen source and thus no odour problem.

It is interesting to note that many scientists think that the hydrogen sulphide and methane which are commonly found in water wells are formed by the action of nuisance bacteria. In the former case, sulphate reducing bacteria live in water deep in the aquifers overlying gypsum beds. These provide an almost limitless source of sulphate. In the latter case, methane bacteria, (commonly found in sewage digesters) feed on the carbonate from limestone beds. This bacteria is not a nuisance organism of distribution systems.

METHODS OF CONTROL

Control of these organisms can be summed up in one phrase "good housekeeping". Basically this consists of eliminating suitable growing environments e.g. by looping mains and preventing dead ends. Also limiting the food supply in the case of iron bacteria. This consists of iron removal and use of non-ferrous piping or mortar-lined pipe. Lastly, control of the organisms can be accomplished by an effective bactericide. Chlorination at very low levels will prevent the establishment of colonies. The free floating organisms have very little resistance to chlorination.

What does one do to remove large amounts of slimy deposits from reservoirs, clear wells and distribution systems? For clearwells and reservoirs the practice of choice has consisted of dewatering, high pressure washing (e.g. fire hoses), scrubbing or soaking with strong (1%) hypochlorite solution (HTH or javex) followed by a final rinse to wash away dead organisms. This of course requires the reservoir to be out of service for some time and may present a problem in maintaining an adequate water supply. To clear distribution systems the problem must be attacked differently.

Marginal chlorination will control nuisance organisms in a new system (by marginal chlorination we mean less than about 0.5 ppm) but will not eliminate them from a heavily infected system. This is because the organic material of the existing colonies will consume the small amount of chlorine present and still leave vast numbers of bacteria alive and healthy to multiply. It is therefore necessary, when initiating chlorination to control these bacteria, to first remove the existing colonies. This has, until recently, meant dosing a section of main with approximately 50 ppm of chlorine, letting it stand for three to four hours then flushing until the water flows clean. The process has to be repeated regularly until two successive flushings yield clean water. Successive dosing is necessary since experience has shown that even very strong solution (200 ppm) will not remove thick slime growths in one application. This method obviously requires many hours and large amounts of water and chlorine. For example 1,000 feet of twelve inch cast iron water main contains approximately 5,000 gallons of water. To chlorinate, you must slowly displace this volume by pumping in chlorinated water at one hydrant while wasting water at the next one. Flushing will require several times this amount at the highest possible velocities and may even require pumping. Thus for each dosing with chlorine we require 20,000 gallons of water. During this process, regardless of the advance notice to customers not to use water, the strong chlorine solution will find its way into service lines and everyone knows what sort of reaction that will bring.

With the availability of the previously mentioned foam swabs, it may be much more practical and economical to perform a mechanical cleaning operation followed by disinfection utilizing the foam swabs to economize on water. It is suggested that after the first swab is run through the second one be driven by water which is heavily chlorinated using a portable chlorinator at the site. A third swab is then introduced and the driving pressure adjusted to give about one hour residence time. The main is then flushed until the water is clean and testing reveals an acceptable chlorine residual. This would be expected to take only a few minutes. This procedure would normally be a one-shot operation and could result in substantial savings in water and labour costs.

SUMMARY

In summary, control of nuisance organisms requires one thing:- good housekeeping.

# CROSS-CONNECTIONS AND BACK SYPHONAGE

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<u>OUTLINE</u> - (1) Definition of terms
(2) Health considerations
(3) Technical considerations
(4) Regulations past and current
(5) Methods of preventing back flow
(6) Common cross-connections
(7) Recent experience with cross-connections
(8) Some case histories
(9) Conclusions

## DEFINITION OF TERMS

### "Cross-Connection"

A "cross-connection" shall mean any actual or potential connection or structural arrangement between a public or consumer's potable water system and any other source or system through which it is possible to introduce into any part of the potable system any used water, industrial fluid, gas or substance other than the intended potable water with which the system is supplied. By-pass arrangements, jumper connections, removable sections, swivel or change-over devices and other temporary or permanent devices through which or because of which "back flow" can or may occur, are considered to be cross-connections.

### "Back Syphonage"

"Back Syphonage" shall mean a form of back flow due to a negative or sub-atmospheric pressure within a water system.

<u>Note:</u>- Above definitions from "Manual of Cross-Connection Control Recommended Practice" - (University of Southern California).

## HEALTH CONSIDERATIONS

Man in his normal environment is vulnerable to insidious attack by many elements which may unknowingly be contained in the water used to supply his personal needs.

It is not the intention here to detail or even name all the ailments that may arise from a supply of impure water but merely to point out that the hazard does exist. If details or proof are required, these are available from medical records.

The fact that these undesirable agents may be invisible, tasteless and odourless makes them difficult to detect and it becomes increasingly important that once a supply of water has been rendered potable that every effort be made to safeguard it and keep it potable.

The purpose of this lecture is to consider the ways in which a potable supply of water can become contaminated and the methods available to guard against such contamination.

## TECHNICAL CONSIDERATIONS

A cross-connection, as we have defined it, is not in itself injurious to health. It is, however, a weak link in the armour of a potable water system. A place where the undesirable elements mentioned above can gain easy access to the supply of potable water.

It is somewhat analogous to a case of dynamite stored in the basement of your home. It may be there for years and do absolutely no harm. It is, however, a constant threat which, under the right circumstances, can become lethal and destructive without notice or warning.

In the case of the cross-connection, the only additional requirements are a reversal of pressure causing a foreign substance to enter the potable water system. If the foreign substance is something injurious to health, then illness and loss of life are apt to follow.

## REGULATIONS - PAST AND CURRENT

In view of the dangers already outlined in association with cross-connections, I believe it may be reasonable to assume that the fight against cross-connections is probably as old as public or communal water systems.

I have no real ancient data on cross-connections but I have some Province of Ontario documents dated 1921 and they seem to indicate that cross-connections posed the same problems in those days as they do to-day. The problem is not new, but it is more important than ever before because every day more and more people depend on a public system for their supply of potable water.

People have at various times enacted legislation outlawing cross-connections, but this has not proved to be a solution to the problem. Things for which there is a demand cannot be legislated out of existance. In this respect cross-connections are like liquor, they refuse to disappear just because they are illegal. Let us not fool ourselves that we are going to stamp out cross-connections over night for it is not likely to happen in this generation or in the next.

Knowing that we do have cross-connections and will, in all likelihood continue to have them, we are making an attempt to regulate and control them and make them as safe as possible. With this in mind, I refer you to the following sections of Regulation 471:

Sections 2; 3; 24; 27; 28; 41; 43; 44 and 153.

## METHODS OF PREVENTING BACK FLOW

### Air Gap

Air gaps in water distribution piping are considered by some people to be the only positive protection against back flow. That a proper air gap will protect a water system is true enough. It loses its reliability, however, because it is so easily by-passed and once this is done, it usually affords no protection at all.

It has another disadvantage in that it usually completely depressurizes the water often necessitating costly re-pumping.

### Barometeric Loop

A barometeric loop is simply a vertical loop of pipe so high above the maximum water level on the downstream side that water cannot be forced back over the loop by atmospheric pressure.

Such an arrangement has the advantage that water need not be depressured and yet will not reverse by syphonic action.

It loses all protective value, however, if the downstream side is subject to pressures other than atmospheric.

Vacuum Breaker

A vacuum breaker offers about the same degree of protection as a barometeric loop. Its advantage is less room required and usually a lower cost price. It is, however, subject to mechanical failure in addition to its inherent limitations.

Check Valves

Where the discharge openings of a water distribution system are submerged and the back pressures are apt to be above atmospheric, back flow cannot be prevented by barometeric loops or vacuum breakers and a check valve arrangement of some kind is usually resorted to.

A single check valve when functioning as intended, will prevent back flow. Check valves are, however, subject to mechanical failure and for that reason a single check valve in a supply pipe is not considered adequate to reduce the hazard to an acceptable level.

If two check valves are installed in series there is still a chance that both may fail but the mathematical probability of both valves failing is less than the probability of one valve failing.

If we further add two gate valves, one before and one after the check valves so the gate valves may be used to isolate the check valves for service and maintenance, the degree of protection is further improved.

The next step is to install test cocks between valves so they may be tested to know when repairs or maintenance are required.

Reduced Pressure Zone Back Flow Preventor

The reduced pressure zone back flow preventor consists of the double check and double gate valve arrangement described above with further refinements incorporated. The reduced pressure zone is the volume enclosed between the two check valves. The reduced pressure is obtained by spring loading the first check valve (in direction of normal flow). In normal operation the water pressure in the reduced zone would always be less than the supply pressure by the amount of the spring loading. Should there be a pressure drop in the supply or a pressure increase on the delivery side with accompanying leakage through the downstream check valve, the reduced pressure zone is kept below the supply pressure by bleeding to atmosphere.

The drain valve from the reduced pressure zone to atmosphere is controlled by a spring-loaded diaphragm. One side of the control diaphragm is subjected to supply pressure and the other to pressure in the reduced zone. The supply pressure tends to close the drain valve. The pressure in the reduced zone plus the spring pressure tend to open the drain valve.

In this way, assuming the worst possible situation, namely, all valves leaking, a back-up of water through the downstream check valve would be drained to atmosphere before the pressure in the reduced zone would build up high enough to force water back through the upstream check valve.

## COMMON CROSS-CONNECTIONS

(a) Any water faucet with a hose connected which can reach a contaminating fluid.

(b) A submerged discharge such as a flushometer water closet.

(c) Direct connected trap seal primers

(d) Fire protection systems cross-connected with potable water systems (sprinkler system).

(e) Fire hydrants cross-connected with polluted ground water.

(f) Water operated devices such as ejectors, aspirators, sprayers, aerators.

## SOME RECENT EXPERIENCE WITH CROSS-CONNECTIONS

(a) Ford & Chrysler Cupola )<br>
(b) Lake Superior pulp mill ) Discuss as<br>
(c) North York Apt. Building and other ) time<br>
heating plant problems. ) permits<br>
(d) East York spot check )<br>
(e) Watts Regulator No. 8 & C-9 )

## SOME CASE HISTORIES

Discuss as time permits some of the cases documented in U.S.A. data.

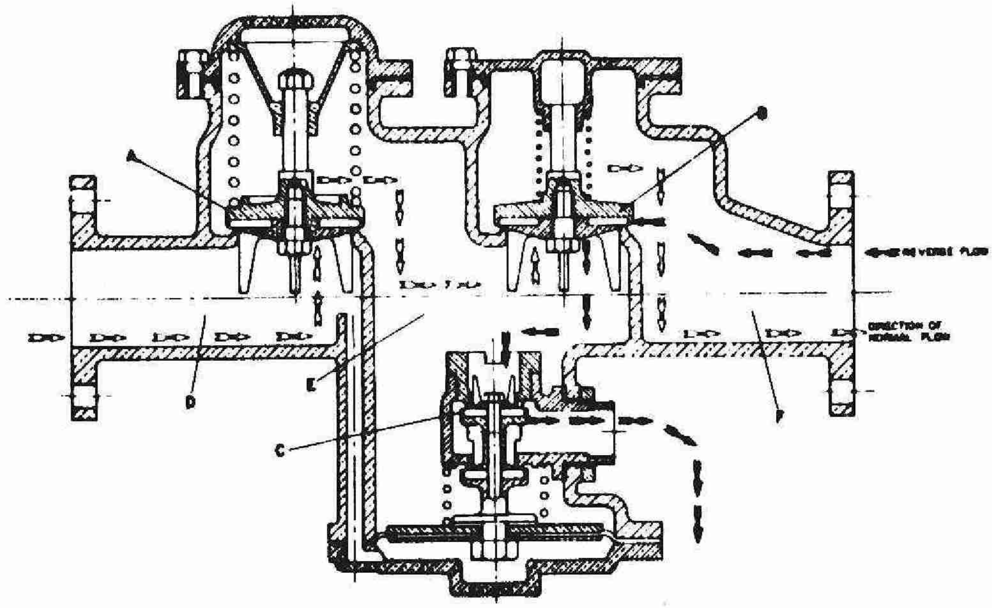
## CONCLUSIONS

In conclusion, no panacea for cross-connections can be offered. It is hoped all water works operators will realize that cross-connections exist all around us and that they are probably here to stay. They are a continual threat to life and health and should be regarded as such. They should be reduced in number to an absolute minimum by eliminating all unnecessary and unprotected cross-connections. Cross-connections which cannot be eliminated should be kept in plain sight rather than hidden away and they should be protected against back flow by the best possible method for the conditions prevailing.

If the probability of contaminating a potable supply through a cross-connection cannot be reduced virtually to zero, then the cross-connection should be eliminated regardless of financial expenditure required.

# F - 7

## REDUCED PRESSURE BACKFLOW PREVENTER




The Beeco Model 6-C Reduced Pressure Backflow Preventer contains the following operating parts:

2 Spring-Loaded Vertical Check Valves (A and B)
1 Spring-Loaded, diaphragm actuated, Differential Pressure Relief Valve (C)

Check Valve A is spring-loaded to a closed position, and causes all water passing through it to be automatically reduced in pressure by approximately 8 pounds per square inch.

Check Valve B, which forms the "double check" feature of the device, also acts to prevent unnecessary drainage of the domestic system in case a backflow condition occurs. This valve is lightly spring-loaded and, therefore, very little pressure reduction is made in passageway F and in the pipe lines beyond.

Relief Valve C is spring-loaded to remain open, and diaphragm actuated to close--by means of differential pressure.

To illustrate the operation, we will assume water, having a supply pressure of 60 psi, is flowing in a normal direction through the device (as shown by the white arrows). If we close all valves beyond Area F, creating a static condition, the water pressure in Area D will be 60 psi and the water pressure in Zone E will be 52 psi.

The inlet pressure of 60 psi is transmitted through a cored passageway to the underside of the diaphragm of Relief Valve C. This valve is spring-loaded to remain in an open position until the differential pressure amounts to 4 psi or more.

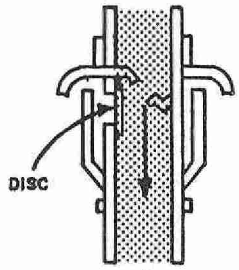
Therefore, during normal operation, the 8 psi differential pressure produced by Check Valve A exceeds the spring-loading of Relief Valve C and causes Valve C to remain closed.

*********************

There are two conditions that tend to produce backflow: (1) decrease in pressure in the supply line, and (2) increase in pressure in the discharge line, or domestic piping system.

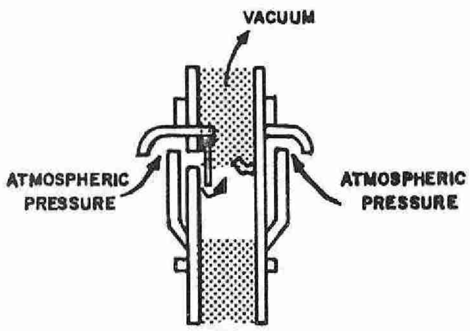
# OPERATION OF A VACUUM BREAKER

## .(I). SWINGING DISC TYPE



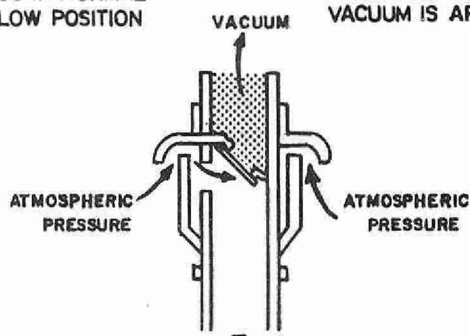

1

DISC IN NORMAL
FLOW POSITION




2

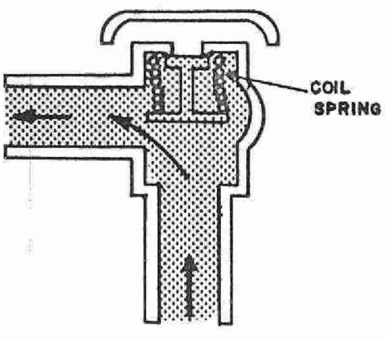
FLOW JUST AFTER
VACUUM IS APPLIED



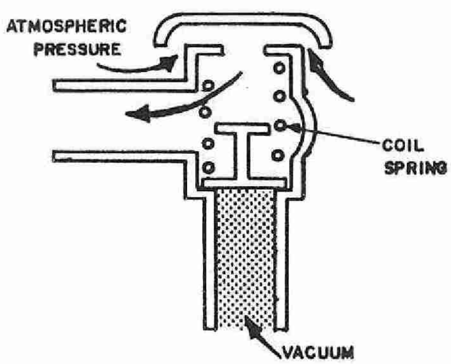

3

DISC IN VACUUM
BREAKING POSITION

## (2) SLIDING SPOOL TYPE




NORMAL FLOW




VACUUM CONDITION

NOTE: This shows the principle of operation.Other types have a sliding spool which closes the air inlet when there is forward flow.

# INSTALLATION & MAINTENANCE OF WATER METERS

W. K. Silk

Sales Representative

## INTRODUCTION

The necessity of properly maintaining consumer meters is the basis of this discussion and should be carried out by trained personnel in a meter shop well equipped to do such maintenance. The major equipment required consists of a test bench of sufficient size to handle a reasonable number of meters at one time, (the size of which should be determined by the number of meters in the system), suitable cleaning facilities such as a sand blast cabinet or acid dip, and other accessory equipment to carry out the work, to ensure that proper re-verification of all meters will be attained.

## DEFINITION

The equity of sale of water to each consumer is dependent on proper maintenance. Water meters of the type used by municipalities in this country begin to under-register as they become worn. Therefore, if meters are allowed to stay in service, in need of repair, their accuracy at low rates of flow deteriorates. The consumer fortunate enough to have an old inaccurate meter on his service will be obtaining water at the expense of others. The loss of water at low rates of flow begins to show a gradual increase in the per capita consumption as the meters fail to record leak flows through hundreds and possibly thousandths of units.

It is necessary to keep consumer meters in good repair, to enable the water department to keep a running check on the metered ratio (unaccounted-for water) by comparison of total readings over a period of time against the readings of master meters feeding the water into the distribution system.

Last and most important, it is essential to keep meters registering accurately, to provide the water department a fair return on the sale of their product so that they may operate on a sound economical basis.

REASONS FOR USING METERS

1) Meters will bring about the elimination of waste of water.

2) Meters will not limit the legitimate use of water.

3) Meters increase the storage in relation to a given population.

4) Meters will conserve water resources.

5) Meters reduce the capital and per capita investment.

6) Meters reduce the cost of operation of the sewage disposal plant.

7) Meters mean more water to the individual citizen.

8) Meters mean less cost of water to the citizen.

9) Meters mean a reduction in the tax rate eventually.

10) 100% metering will reduce the water to be supplied 40 to 60%.

Water meters act as the cash register or policeman for the water department. All water meters will operate and give reasonable accuracy at medium and high rates of flow, even if in poor mechanical condition, but it must be remembered a great percentage of the water used in a home is at the rate of flow of below 3 or 4 gallons per minute. In tests conducted in Hartford, Connecticut, it was found that in homes equipped with tank toilets, 27 to 50% of the total amount of water used was at a rate of flow of less than 1 gallon per minute. Therefore, it is vitally important that the accuracy of water meters be preserved below the flow of 1 gallon per minute. If leaks occur, the meter is going to be called on to provide reasonable accurate readings below this rate. It does not take the home owner long to realize that the amount of water which leaks away, when a leaky tap or toilet is left unattended, is considerable. For example, a leak running at 1/20 of a gallon per minute will allow 2,160 gallons per month to go to waste, which is sufficiently adequate to supply a family of four for the same period of time. Multiply this by 10 - 50 or more, and you can readily see how much waste can and does occur if meters are not registering accurately at the low rates of flow. It is surprising to discover

that some water departments pay little attention to the water meter after it has been bought and installed. In some, the water meters are actually allowed to remain in service until such times as they fail to register.

A simple method of detecting a leaking toilet in the domestic system (the most common cause of undetected leaks) is to put a few drops of food dye in the tank, after approximately 15 to 20 minutes if the water in the bowl shows traces of the colour, there is obviously a leak.

## STANDARD TEST SPECIFICATIONS

Let us draw a comparison between three types of utility services: - water, electricity and gas. It is universal practice to meter gas and electric energy. By Dominion Government law (the Standards Division of the Department of Consumer & Corporate Affairs), it is mandatory to check, at stated intervals, the accuracy and possible need of repair on these gas and electric meters. However, after an investigation into the same practice regarding water meters it was decided that it was not necessary. They found all meters manufactured and offered for sale on this continent, and in general use domestically, conform to the specifications of the American Water Works Association whose test requirements were adequate. The A.W.W.A. test specifications for a 5/8" meter are as follows: Meters must register between 98.5% and 101.5% within normal test flow limits of 1 to 20 U.S. g.p.m. and at least 95% at the minimum test flow of 1/4 U.S. g.p.m. Also, nearly all of our municipalities using water meters already had installed test equipment and were conducting accuracy checks at regular intervals. The water meters used in this country on domestic services of the nutating disc or oscillating piston type will not over-register beyond the allowable limits of plus 1-1/2% due to wear or any other cause.

Possibly we should point out here that the A.W.W.A. test specifications for repaired meters differ somewhat from that for new meters. Once again, for a 5/8" meter the test specifications, for repaired meters, are the same as new meters within normal test flow limits of 1 to 20 U.S. g.p.m. and 90% or better at the minimum test flow of 1/4 U.S. g.p.m. Further, the actual test flows and quantities are as follows: Maximum rate 15 g.p.m. with a test quantity of 100 gallons or 10 cubic feet. Intermediate rate of 2 g.p.m. with a test quantity of 10 gallons or 1 cubic foot. Minimum rate of 1/4 g.p.m. with a test quantity of 10 gallons or 1 cubic foot.

From the above, it is therefore evident that the maintenance and test period for 5/8" domestic meters, in particular, should be determined by the individual utility.

## WATER CHEMISTRY

The quality of water varies greatly across Canada. Many of the water supplies in the Prairies are of an alkali condition which promotes accelerated wear and deterioration. In some localities in the Maritimes, where supplies are from springs, the water has traces of sulphur which may defy entire elimination, and provides an acid condition which promotes more rapid deterioration of valves, piping, fittings, meters, etc. Generally, however, in Ontario surface supplies such as the Great Lakes and supplementary rivers have an excellent quality of water from a metering standpoint. This provides increased length of service for meters under normal service conditions.

## METER SIZING

The proper sizing of meters will also have a bearing on your maintenance program. Meters supplied to A.W.W.A. specifications, or generally meters manufactured on the North American continent, are amply sized to easily take care of the full flow of the same corresponding size of service pipe. For example, a 5/8" meter has a maximum rated capacity of 20 U.S. or 16.5 Imperial g.p.m. This information for all sizes of meters is readily available from the manufacturer or A.W.W.A. Meter Manual M.6. Naturally if a meter is undersized, it may be grievously over-worked and require more frequent attention to keep it within the test specifications. Where there is any question, a chart recording register can be utilized to determine the maximum and normal rates of flow. It is of considerable value in assisting you to determine the correct size of meter, particularly on services of 3" size and larger. For example, it may be possible to install a 3" meter on a 4" or 6" line if the demand is within the flow limits of the meter and the resulting increase in head loss is of little or no importance.

## RECONDITIONING INTERVAL

From the foregoing it should be evident that no definite re-verification program is applicable to all municipalities across Canada. Conceivably a meter in

Brockville could be in better condition both mechanically and sensitively after 15 years service than one in some portions of Western Canada or even in some municipalities in Southwestern Ontario. Obviously it is not possible to decide that because a certain municipality checks its meters every 7 years that this should be the same for any other. Considering quality of water, perhaps we could say that all water supplies from the Great Lakes System should be uniform. This would apply only if all rates, pressures, and even prosperity of the users, were the same. Each water works should endeavour to determine for themselves the interval for reconditioning. In many instances the greater percentage of 5/8" meters in many municipalities could be left as long as 15 years and in others perhaps 5, 6 or 7 is indicated. Meters of the same 5/8" size, which have a heavy use on commercial services, should have a more frequent check. However, generally speaking domestic size meters should be checked within a 10 year period.

In some water departments the repair and test period is based directly on the amount of water passed through the meter. From the standpoint of the meter, this may be the best method, but from the utility standpoint it is inefficient and costly.

Municipalities who have had meters in service for many years without periodic repair, carried out only when stoppage results, should contact the meter manufacturer for a listing of serial numbers and the year of manufacture, from which groups of 5/8" meters can be selected varying in age and average service. These meters can be given a thorough accuracy test as removed. Care should be taken to cork the inlet and outlet so that the meter will not dry out and test as soon as possible after removal from service. Of course, the tested meters should be, if it can be determined, meters which have not been repaired since the original installation. Following the above procedure and using rates of flow suggested by A.W.W.A., accurate data can be acquired as to the proper length of time for carrying out periodic inspection.

Care must also be taken in the handling of these sample meters to ensure that scale or other foreign matter in the meters is not dislodged in transportation or while installing on the test bench, otherwise false test results are likely to be obtained.

So far the larger sizes of meters have not been mentioned as the 5/8" or domestic meter is in use in such relatively large numbers, and incidentally of much greater

importance from a low flow loss standpoint. Small leaks are more apt to occur in the house services due to the numbers of outlets and also the large number of services. Leakage waste is more often found in the domestic service rather than industry, although wasteful use in large quantities and at higher rates of flow do occur in some industries. As previously mentioned, the displacement meter is very unlikely to slip in its registration at the higher rates of flow. It first starts to deteriorate at low or leak rates which is an indication that it is time it should be rehabilitated.

It is usual practice to remove 5/8" to 2" meters from the services for periodic inspection and test, replacing them with others on the services. Repairs and testing are carried out in the water works repair department.

Water meters larger than 2" are usually checked for accuracy on the installation as it is not economical in an average size municipality to have spare units on hand. The cost of removing and re-installing has also to be considered along with the equipment which would be required to carry out such a project.

The larger sized meters are responsible for the recording of large volumes of water and hence if inaccurate, result in greater loss of revenue to the utility. They therefore should be checked, if not repaired, much more frequently. Many municipalities check all 3" and larger meters annually. Provision on each installation should be made to allow this to be carried out. All installations should be made with a by-pass and sealed valve so that the meter can be checked in service without interruption of same to the customer, at any time.

If the meter is not equipped with a test plug, a test tee should be installed at the meter outlet so that a 2 or 3" positive displacement test meter can be used as the test unit. It is connected by hoses to the meter to be checked for accuracy or repair. The service being provided by the by-pass while tests or repairs are being conducted. The water passes to waste through the service meter and test meter. By comparing the readings, the service meter's condition can be determined. If the installation is properly made for such tests, the efficiency of a large meter can be obtained in a minimum of time with relatively inexpensive equipment. The majority of meters 3" size and up could well be checked annually in the above manner and for such test results, the period

of proper time to clean, repair and recalibrate becomes evident. It is most important that the test meter should be checked often on the water meter test bench to insure its accuracy.

You will notice that the A.W.W.A. Meter Manual No. M.6 has been referred to previously which provides an excellent guide for those intending to carry out periodic inspection of meters. Chapter 7 of this article is quoted here.

----Although it has taken a great many years to obtain general acceptance of the use of water meters as the most equitable basis for charging for water service, full benefits from metering are not obtained unless a definite program of meter maintenance is carried out.

## PURPOSE OF TESTING

A water meter, like any other mechanical device, it subject to wear and, over a period of time, loses its peak efficiency. How long water meters retain their overall accuracy depends largely on the quality of water being measured. There are several other factors, however, that cause excessive wear or inaccurate registration. Obviously, although the only way to determine whether any specific meter is operating efficiently is to test it, the problem of establishing a meter maintenance program is how to determine the frequency for testing every meter in service. From an individual customer's viewpoint, meters should be tested to protect him against meter inaccuracy that could result in over charges. This, of course, is also of concern to utility management. Experience shows, however, that the greater concern of a water utility should be the revenue lost that results from the under-registration of meters.

The economic advantage of meter maintenance programs has been recorded in many articles, but most of them have invariably covered concentrated efforts to rehabilitate meters after a long period of non-maintenance and are of little value in answering the question of how often meters should be tested under a program of meter testing on a sustained, continuous basis. Unfortunately, there can be no single answer, as the economic result depends on such factors as the rates charged for water, the effect of waters of different quality on meters, and the cost of removal, testing, repairing, and the installation of meters. A reasonably proper economic balance should be attained. If meters are not adequately maintained, loss of revenue to the utility results. Conversely, if the cost of a program of meter maintenance is more than

the loss of revenue that would occur if the meters were not tested, the overall result is economic waste and the utility's customers are required to pay for unnecessary expense.

TEST FREQUENCY

Although many municipalities have adopted regulations concerning frequency of meter test, it should be noted that any arbitrary time interval applied to several localities, each with its own local conditions, cannot be economically correct for all. It must be recognized, however, that the very existence of such regulations has often caused meters to be better maintained than without such regulations. It is inexplicable, but true, that meter maintenance in too many instances is considered of little importance, as something which is often done only when other types of work, which cannot be readily deferred, are out of the way. Only when meters are truly recognized as the only means by which revenue is obtained to operate the water system, will the necessary time and study be given to the question of how frequently it is necessary to test meters for most efficient and economic results.

What are some of the things that must be known in order to establish time or registration intervals between tests? One, of course, with a fully metered system is to the percentage of water delivered to the distribution system which is registered by customers' meters. This is known as the "metered ratio". The expression "percentage accounted for" is not used here, as there are so many methods and basis for estimates of unmetered uses that comparisons of water accounted for are often meaningless. If a low percentage of the total delivered to the distribution system in a year, such as 60 to 70%, is recorded by all customers' meters, this is indicative of inefficiency, and may be the result of under-registration of meters, undue leakage in mains and services, or the combination of both. Even when a water system is only partially metered, a marked variation in the percentage from year to year should be investigated.

Practically no study that is made, however, can tell how much of the loss is due to the under-registration of meters. This amount can only be determined by testing. Some indication can be obtained by installing new meters in series with old meters in service and, by selective sampling, projecting the probable loss due to under-registration for meters that have been in service for a certain period of years. If meters of different makes and various models are used, such sampling can become quite complex

and the results may be of dubious value. There is, however, a very distinct value in such in-service comparisons - that is, to show conclusively how much under-registration and resultant loss in revenue occurs if meters are not maintained in good operating condition.

PROGRAM CO-ORDINATION

To start a program of periodic testing, it is necessary to adopt an arbitrary period in which to complete the work, and it is desirable to select a period of years that coincides with the best estimate of frequency with which meters should be tested. In this way the work is levelled out, and the next time the meters are tested, nearly the same number will be due for test each year. If, for example, a utility with 10,000 meters in service sets up a program for testing meters on a 10 year cycle, it has to remove approximately 900 meters each year. This is less than 10% of the number in service, as there are always meters that will not remain in service for the full period and will be removed for other reasons. In order to provide for even work flow, both in the changing of meters and shop work, it is preferable to have the number of orders required prepared on a daily basis. Assuming there are 250 working days in a year, to complete the periodic testing of 900 meters per year, the testing of roughly 4 meters each day would be necessary in addition to the other required work. If, therefore, 4 orders are written each day, progress of the program may be reviewed at any time by a count of the number of uncompleted orders for changing meters for periodic test, and a check to see if the shop work is getting done without building up a backlog of meters. Although the testing of 10,000 meters may seem a staggering job, it is surprising, once the work is started on a systematic basis, how the additional work is absorbed as it soon becomes routine. Obviously as actual test results of meters removed from service are accumulated, experience is obtained as to the length of time it takes, on the average, for meters to lose sensitivity on low flows and the length of time meters are permitted to remain in service can be adjusted on the basis of known results.

It is generally considered advisable to provide for more frequent tests of large meters, on the logical premise that an error in their registration affects revenue to a much greater extent. Furthermore, Current and Compound meters may over-register to a much greater degree than positive displacement meters. If a sufficient number of 3" or larger meters are installed, the repair and testing of these larger meters may be delegated to one particular

person or crew and divorced from the normal procedure set up for handling maintenance of small meters.

Probably the best advice which can be given on this involved and difficult problem is to be alert to, and study all phases of, the subject, as there is no substitute for experience in arriving at the best answer. It should be constantly borne in mind, however, that although a metered system is the best basis known for equitably spreading the cost of the water service, serious inequities and injustice can be introduced unless all meters are maintained at high, uniform level of efficiency and unless every reasonable effort is made to see that these inequities do not occur.

"The American water Works Association believes that every water utility should meter all water that it takes into the system and all water distributed from the system to all users. Changes in standards of living have produced an increasing diversity in the use of, and the demand for, water among domestic customers and have thus made flat rates less and less likely to be equitable. At the same time, the increasing cost of developing, treating and distributing water had meant that the close control of all operations made possible only by meters is more and more critical. Only by universal metering can efficient control over system operation be maintained and only on this basis can equitable charge be made to each user."

The foregoing statement was adopted by the A.W.W.A. Board of Directors on January 26th, 1969.

# WATER MAIN BREAKS

J. H. Miller

Field Sales Manager,
Stanton Pipes Limited

## INTRODUCTION

We know that November each year sees the beginning of the water main failure season.

Obviously water utilites become concerned whether their main breaks are considered excessive.

Some water men feel that three breaks in their system in one year is outrageous. Others accept ten breaks in one evening, as commonplace.

What factor should be used to decide whether a water system is adequately designed, properly installed, and satisfactorily maintained?

## SURVEY RESULTS

In order to obtain some of the answers to this question we recently conducted a survey amongst 54 Ontario municipalities operating nearly 5,500 miles of mains. We asked the following questions:
(1) What is your source of supply? Surface or wells?
(2) How many breaks did you have in 1968 in the 4" to 12" sizes?
(3) Which were your three worst months for failures?
(4) What kind and class of pipe are you now installing?
(5) What type of bedding do you specify for your main installation?

As a result of the survey, we learned that municipalities on an average had a break every 3.3 miles.

The survey indicated the following:

| Diameter | Total Miles of Main | Miles Per Break |
|---|---|---|
| 4" | 449 | 3.7 |
| 6" | 3,568 | 2.7 |
| 8" | 592 | 5.2 |
| 10" | 213 | 9.3 |
| 12" | 626 | 12.8 |

Obviously some concern must be given by all water men to 4" and 6" pipe with regard to the proper selection of design and installation criteria.

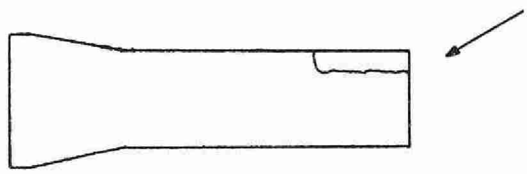
If a utility; comparing its 1968 main breaks with the survey; finds itself below average in any or all diameters listed; it should seriously consider increasing the safety factor in its pipe selection, and/or improving the installation bedding conditions.

Southwestern Ontario area considered December, January and February as their worst three months for breaks. January, February and March were bad for the south central region. Eastern Ontario were upset with February, March and April. The Lakehead had major difficulties in March, April and May.

DIAGNOSING THE MAIN BREAK

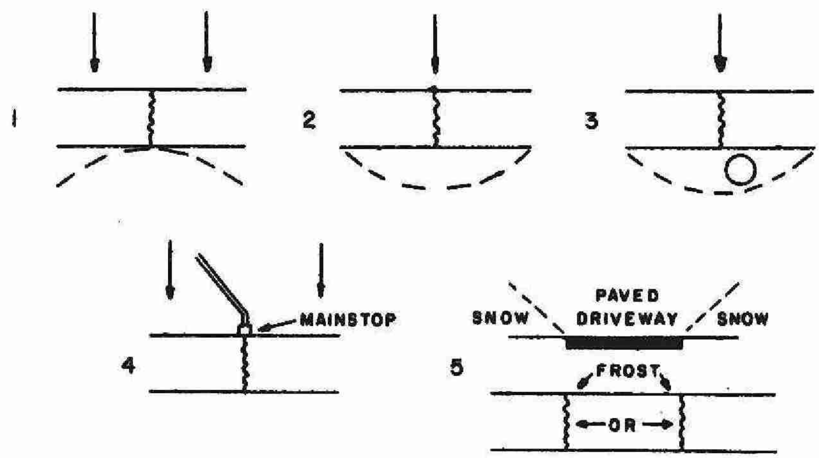
It is useful to consider the various visual aspects of a main break. These themselves help us to diagnose the reason for a failure.

(A) Impact



The longitudinal tear usually occurs under test pressure; and is a direct result of impact to the spigot end, before or during installation. This may occur due to improper unloading of trucks; i.e. throwing pipes off the truck, rather than unloading with mechanical or controlled means. Impact can also occur when pipes are thrown into the trench hitting a previously installed pipe. Rocks falling in off the sides, or when backfilling, can also cause impact.

(B) Frost Penetration



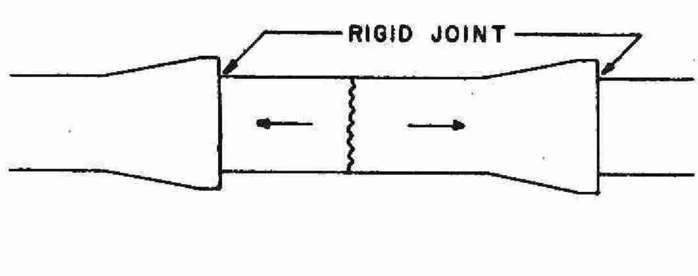

Frost, by itself, does not break pipes. However, in Figures (1) and (2) we see that improper bedding aids frost in creating circumferential failures.

A sewer pipe installed laterally without proper support to the water main (as seen in Figure 3) promotes a similar failure as in Figures (1) and (2).

A circumferential break at the main stop (see Figure 4) is caused by the service pipe being held rigid by the frozen ground while the frost penetration creates excessive stress on the rest of the pipe.

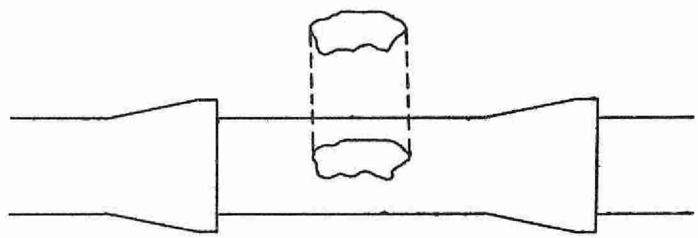
Many breaks are due to the streets and driveways being kept clear of snow. The snow piled high off to the side of the pavement, acts as a ground insulator, preventing frost penetration. While the clean pavements encourage a greater depth of frost. See Figure 5.

(C) Main Contraction



Systems that are supplied with a surface source of water are susceptible to a wider range of temperature changes than well supplies. Contractions and expansions in the rigidly jointed water mains can cause circumferential breaks. The modern rubber gasketed flexible joint should offset this problem.

(D) Hammer and Air Lock

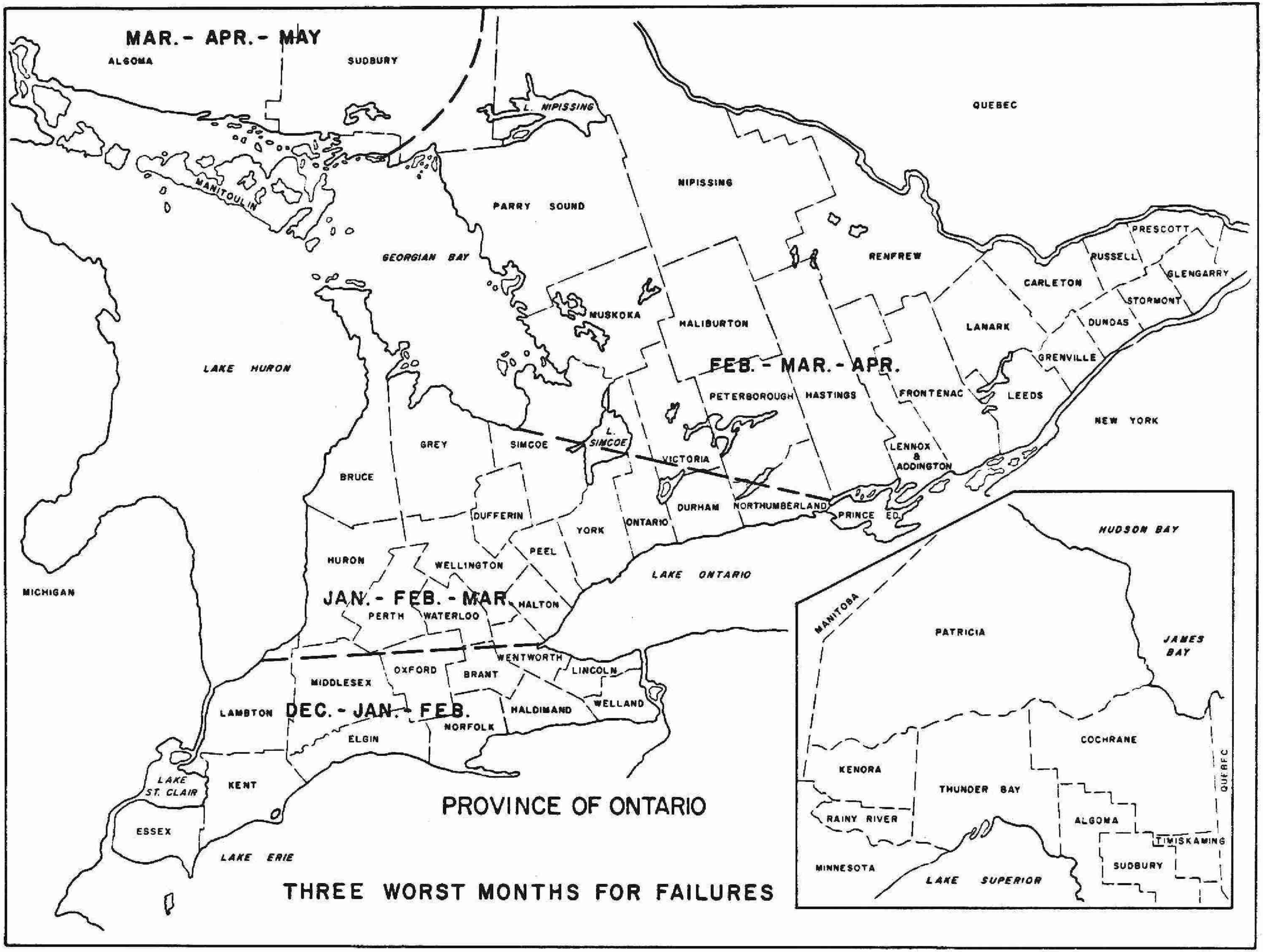


Pressure testing a water line without releasing all the air at the high spots can burst a pipe. Quick closure of a valve, creating water hammer, can give the same result. This can be evidenced when a whole section of the pipe has come away.

CONCLUSION

In order to keep breaks to a minimum; the following should be given careful consideration when designing and installing a water line:

(A) Select the proper class of pipe for the job.
(B) Reliable inspectors should be on the site at all times to supervise the off loading and installation.
(C) Ensure that the main is installed to minimum standards of "no blocking, flat bottom trench, and tamped backfill".
(D) Do not permit the undermining of the water line by other utilities without adequate support.
(E) Make certain that air relief valves are installed; especially if main is located in hilly area.
(F) Do not permit operation of valves or hydrants by unauthorized personnel.
(G) Do not tap services into the top of the main. Recommended locations are at "10 O'Clock" and "2 O'Clock"
(H) Evaluate every break by filing a "Water Main Failure Report". The A.W.W.A. report as listed below can be reproduced and used to an advantage in your area.


MAR. - APR. - MAY
FEB. - MAR. - APR.
JAN. - FEB. - MAR.
DEC. - JAN. - FEB.
PROVINCE OF ONTARIO
THREE WORST MONTHS FOR FAILURES
ALGOMA
SUDBURY
QUEBEC
L. NIPISSING
MANITOULIN
NIPISSING
PARRY SOUND
GEORGIAN BAY
RENFREW
PRESCOTT
RUSSELL
GLENGARRY
CARLETON
STORMONT
MUSKOKA
HALIBURTON
LANARK
DUNDAS
GRENVILLE
LAKE HURON
PETERBOROUGH
HASTINGS
FRONTENAC
LEEDS
NEW YORK
GREY
SIMCOE
L. SIMCOE
VICTORIA
LENNOX & ADDINGTON
BRUCE
DUFFERIN
DURHAM
NORTHUMBERLAND
PRINCE ED.
YORK
ONTARIO
PEEL
HURON
WELLINGTON
LAKE ONTARIO
MICHIGAN
HALTON
PERTH
WATERLOO
WENTWORTH
LINCOLN
OXFORD
BRANT
MIDDLESEX
WELLAND
LAMBTON
HALDIMAND
NORFOLK
ELGIN
LAKE ST. CLAIR
KENT
ESSEX
LAKE ERIE
HUDSON BAY
MANITOBA
PATRICIA
JAMES BAY
COCHRANE
KENORA
THUNDER BAY
QUEBEC
RAINY RIVER
ALGOMA
TIMISKAMING
SUDBURY
MINNESOTA
LAKE SUPERIOR

NO. ____________

## WATER MAIN FAILURE REPORT

### FIELD DATA FOR MAIN BREAK EVALUATION

DATE OF BREAK ____________ TIME: ________ A.M. ________ P.M.

TYPE OF MAIN: ____________ SIZE ________ JOINT ____________ COVER ______ FT. ______ IN.

THICKNESS AT POINT OF FAILURE ________ INCH.

NATURE OF BREAK: Circumferential ☐ Longitudinal ☐ Circumferential & Longitudinal ☐ Blowout ☐ Joint ☐

Split at Corporation ☐ Sleeve ☐ Miscellaneous ____________ (describe) ☐

APPARENT CAUSE OF BREAK: Water Hammer (surge) ☐ Defective Pipe ☐ Corrosion ☐ Deterioration ☐

Improper Bedding ☐ Excessive Operating Pressure ☐ Differential Settlement ☐ Temp. Change ☐ Contractor ☐ Misc. ____________ (describe) ☐

STREET SURFACE: Paved ☐ Unpaved ☐ TRAFFIC: Heavy ☐ Medium ☐ Light ☐

TYPE OF STREET SURFACE ____________ SIDE OF STREET: Sunny ☐ Shady ☐

TYPE OF SOIL ____________ RESISTIVITY ________ ohm/cm

ELECTROLYSIS INDICATED: Yes ☐ No ☐ CORROSION: Outside ☐ Inside ☐

CONDITIONS FOUND: Rocks ☐ Voids ☐ PROXIMITY TO OTHER UTILITIES ____________

DEPTH OF FROST ______ INCH DEPTH OF SNOW ______ INCH

### OFFICE DATA FOR MAIN BREAK EVALUATION

WEATHER CONDITIONS: PREVIOUS TWO WEEKS ____________

SUDDEN CHANGE IN AIR TEMP ? Yes ☐ No ☐ TEMP. ______ °F. RISE ______ °F. FALL ______ °F.

WATER TEMP.: SUDDEN CHANGE: Yes ☐ No ☐ TEMP. ______ °F. RISE ______ °F. FALL ______ °F.

SPEC. OF MAIN ____________ CLASS OR THICKNESS ________ LAYING LENGTH ______ FT.

DATE LAID ________ OPERATING PRESSURE ______ PSI. PREVIOUS BREAK REPORTED ____________

INITIAL INSTALLATION DATA:

TRENCH PREPARATION: Native Material ____________ (describe type) ☐ Sand Bedding ☐ Gravel Bedding ☐

BACKFILL: Native Material ☐ DESCRIBE ____________ Bank Run Sand & Gravel ☐

Gravel ☐ Sand ☐ Crushed Rock ☐ OTHER ____________

SETTLEMENT: Natural ☐ Water ☐ Compactors ☐ Vibrators ☐ OTHER ____________ (describe)

### ADDITIONAL DATA FOR LOCAL UTILITY USE

LOCATION OF BREAK ____________ MAP NO. ________

REPORTED BY ____________

DAMAGE TO PAVING AND/OR PRIVATE PROPERTY ____________

____________

REPAIRS MADE (Materials, Labor, Equipment) ____________

____________

REPAIR DIFFICULTIES (If Any) ____________

____________

INSTALLING CONTRACTOR ____________

# CAST IRON MAIN BREAK REPAIRS
# 4 INCH - 12 INCH (INCLUSIVE)

J. Lasenby

Construction & Plant Shops Superintendent
London Public Utilities Commission

A broken main is an unplanned event and for this reason trained personnel, records, maps, repair parts, etc., must be available.

In our system we maintain a serviceman on duty for 16 hours out of 24 hours with a back-up serviceman and foreman available. The foreman on call throughout the 24 hour period, for seven days, working his normal day shift with a second serviceman to provide assistance from 5:00 p.m. to 8:00 a.m. This serviceman would be first called after the hours of 1:00 a.m. to 8:00 a.m. the following morning.

A central control or operating centre is necessary where all calls can be received and acted upon. This is our Operations Centre which is manned 24 hours a day each day of the week.

1. When a main breaks the first consideration should be to get the water under control, by a complete or partial shut-down.

2. Record the valves operated and their operating condition.

3. Report the section of system that is out of service and report all hydrants that are affected to the Fire Department.

4. Notify the affected consumers of the shut-down, including buildings with sprinkler systems, water-cooled refrigeration units, etc. If these buildings are unoccupied notify the owner, manager or agent.

5. Survey the area for any visible damage or flooding that has taken place. Snow and ice will be melted or earth deposited along the course the escaping water has followed.

6. Record your actions and procedures followed. Your Utility may be held liable if others have suffered damage from the escaping water and shut-down.

7. It may be necessary to arrange for Police assistance for the directing of traffic.

8. The Safety of the workmen and the general public must always be considered.

9. The following could be common to a main break:

   Under-mining of roads, walks, railways, other utilities, etc.

Slippery driving conditions caused by flooding or freezing water. Arrange for salt and sanding operations if necessary.

Flooded basements.

Plugged or restricted sewers.

10. Minimum requirements for Waterworks trouble trucks:

An up-to-date valve book.
Dip needle.
Complete set of keys to fit all valves.
Pick axe.
Sledge hammer.
Propane burner to thaw frozen valve chambers.
Manhole cover lifter.
Two short-handled pointed shovels.
Flashlight.
Barricade and lights.
Set of geophones.
Two hydrant keys.
100 feet of linen tape.

11. The first series of slides will show equipment and materials normally used to facilitate repairs.

View 1A The valve book showing the lay-out of the system.

View 1A1 Measurement for valve location.

View 2A The dip needle for locating valves - M-scope and Geophones.

View 3A Valve key, pick, manhole lifter, shovel, burner.

View 4A Safety equipment barricades, flashers, cones, men working signs.

View 5A Pipe cutters and saw.

View 6A Materials: clamps, couplings, mechanical joint sleeves, pipe.

View 7A Generator and lights for night use.

View 8A Truck 76 - supervisor's vehicle.

View 9A Truck 82 with compressor and gun.

View 10A Tractor back-hoe and loader.

View 1B Shows the work area with the valve key in the background showing the watermain shut-off. Before starting to excavate other utilities should be contacted - i.e. Bell Telephone Company, Gas Company, Hydro Company and Sewer Sections. A clearance should be obtained from those utilities to ensure that there is no underground plant buried within the excavation area that is proposed. Failing to

obtain a proper locate or a locate of any kind could result in further damage to another utility's system.

View 2B Shows the compressor on site, suitable barricades to protect both the workmen, traffic and pedestrians from the excavation area. You will see the use of Geophones being used to define the point of break. It is only through adequate experience and prolonged use that an employee can be proficient in interpreting the sounds picked-up from the Geophones. It is recommended that you cross-check in both directions with the Geophones listening for the most audible sound indicating the point of rupture. The water would be turned on for this operation.

View 3B Compressor breaking frost.

View 4B Another method that is used to determine the point of break is the use of a heavy duty post-hole auger equipped with a frost cutter; by putting down a series of test-holes you will soon locate the void under the frozen earth.

View 5B You will note here there is a second test-hole in place with the water flowing.

View 6B The frost has been sufficiently dug away to use a tractor back-hoe loader to complete the excavation.

View 7B The materials are being loaded onto a dump truck and will be drawn off the site. The excavation will be back-filled with suitable compaction materials to safe-guard against any subsidence within the road allowance causing damage to vehicle, traffic, etc., after the repair is completed.

View 8B Shows the watermain break - circumferential - typical on this type of pipe. This is the most common type normally encountered and accounts for 80% of the main breaks in the London system.

Total main break incident for 1968 = 116.

View 9B Shows the workmen removing a piece of wooden blocking. It is interesting to note that this watermain had been installed over forty years when this failure occurred.

View 10B The wood blocking is in remarkably good condition and well preserved for being buried forty years under the watermain. This blocking is probably the reason for the main failure.

View 11B Here is the typical repair clamp used. There are several types on the market today- much of the same style and character of the one seen in the photograph.

View 12B Here the employee is holding it showing the clamp being separated ready for installation.

View 13B A view of the opposite side of the clamp.. 6 inch cast iron.

View 14B This view shows the clamp and its two halves, note the finger arrangement for the sealing of the ends. Care should be taken when the clamp is installed that the fingers are adequately and properly seated in its corresponding mating groove. This style of clamp has been revised.

View 15B Here the clamp is being installed, the pipe has been cleaned with a wire brush and cloth, sterilized by pouring a solution of H.T.H. over the ruptured area, the clamp should be tightened in a systematic manner going from one bolt to another and pulling it up snug enough to prevent any leakage.

View 16B These bolts should be pulled tight using a wrench of 12 inches in length.

View 17B The water is turned on and the repair is being checked.

This second series of film that we are going to view is a different type of repairs. This is the repair that is more common in the old cast iron watermains, the type with the run-joints, and is very common in the London area in the extreme winter conditions and with the lower temperature of water.

View 1C Shows the general work area, the vehicles on site, pump, tractor back-hoe and the area barricaded.

View 2C The excavation is started and the material excavated being loaded to be taken off the site.

View 3C The spigot broke flush with the bell. It will be necessary to cut a section out of the pipe on either side of the bell and spigot and insert a new piece.

View 4C Shows the material common to the type of repair that is underway, namely, a piece of pipe to be inserted in the cut-out section, the mechanical sleeves to marry it together, H.T.H. or pitchlor to sterilize the broken area and the materials to be inserted. On older type cast iron the O.D. in some cases is of a larger diameter and the mechanical sleeves will not fit unless they are machined out to increase the I.D. to accommodate the old style pipe.

View 5C Here we see two employees delivering water to the householders. The method of delivery here is the old familiar milk can. These milk cans would be filled-up at the service depot or at an area that is not in the affected system that is shut-off. Each householder would be delivered a can of water or a portion of same. Plastic containers may also be used.

View 6C Here is an excellent view showing the broken section. You will note the corrosion that has taken place around the run joint and the break coming flush with the bell end of the pipe.

View 7C Here we see the new section of pipe ready to be installed and because of the O.D. of the existing pipe in the system transition couplings are being used to accommodate the over-sized diameter on the old pipe that it will be married to.

View 8C Shows the H.T.H. slurry being applied to the pipe section and materials to be inserted in the watermain.

View 9C Here we see the section installed, complete with couplings. The new piece has been inserted. The couplings are securely tightened and fastened and the water has been turned back on to make sure that there is no leakage from the couplings. Always charge the system slowly opening hydrants on the high point to expel the air from the line.

View 10C Here you will see that the excavation has been dried out and the use of denso tape and paste has been employed to wrap the couplings to prevent corrosion.

View 11C The blocking that had been used underneath the pipe to facilitate its installation has been removed and the excavation is being filled with granular material and compacted.

WHAT DOES A MAIN BREAK DO?

1. It can cause considerable damage to surrounding structures. The undermining of buildings, sewers, pole-lines and other buried utilities, requiring expenditures of considerable amounts to correct the repair.

2. It can cause inconvenience to our customers and affect our public relations.

3. It will be an added and unexpected expense to your maintenance budget.

4. It will disrupt the plans and schedules you have made for your work crews for that day.

5. In all likelihood it will take place in the hours when your employees will be in the premium time area and your labour could be one and one-half or two times the normal cost of undertaking the repairs.

JL*cc

# INSTALLATION, OPERATION & MAINTENANCE OF GATE VALVES

Wally Beach

Canada Valve Limited

This standard is issued as a recommendation to the customer concerning the proper use of gate valves.

## INSTALLATION:

(a) When valves are received they should be handled carefully to avoid distortion, breakage and damage to flanges and seats. Have valves in the closed position until time for installation. Protect stored valves from the elements if possible.

(b) Before installation clean foreign material from piping.

(c) Install valves in the line making sure that both pipe and valve are adequately supported so that line stresses are not transmitted to the valve body. Do not use a valve as a final joint to correct any error in piping alignment or spacing.

(d) In the case of flange end valves, tighten flange bolts uniformly and in stages. Pull up bolts on diametrically opposite sides of the flange until all bolts are uniformly tight and the joint gasket has sufficient compression to prevent leakage at the test pressure.

(e) In the case of screw end valves, make sure the pipe does not screw too far into the valve and damage the seat rings. Apply pipe compound to the male thread only. Do not force pipe into a screw end valve.

(f) Certain valves, such as square bottom or automatic drip valves, are designed for one way flow. The direction of flow is indicated by an arrow cast on the body.

(g) Check for proper operating clearance when installing valves.

OPERATION:

(a) Direction of opening is indicated by an arrow cast on the handwheel or wrench nut of the valve.

(b) Operate gate valves from full closed to full open position and back before applying pressure.

(c) Close gate valves slowly against pressure to avoid damage from surge or water hammer.

(d) Valves installed on liquid service subject to freezing conditions should be protected to prevent trapping of liquid between discs, expansion on freezing and subsequent damage. The same is true of valves subject to considerable temperature increases, especially on volatile liquids. Trapped pressure should be vented back to the upstream side to prevent build-up of pressure in the valve bonnet due to high temperature expansion.

MAINTENANCE:

(a) Operate gate valves from full open to full close at regular intervals. The length of time between operations depends on the time of installation and the service conditions.

* (b) Keep the stem thread and packing lubricated. Hydraulic oil for the packing and graphite grease for the stem thread are suggested.

* (c) Check the packing for leakage at regular intervals. If leakage cannot be stopped by drawing down on the packing, the valve should be repacked.

* (d) On repacking a valve, be sure to check the valve service and obtain the proper packing. To obtain packing that will fit the stuffing box from the factory, forward the information cast on the side of the valve body and order the packing for the quantity of valves to be repacked.

* (e) To repack a valve, run the valve to the full open position and back seat the stem tightly against the bonnet. It will then be possible to repack under pressure.

(f) Gate and seat surfaces may become damaged or scored in operation. These surfaces may be refaced in the field. Disassemble the valve and reface in a standard lathe, making sure the seat ring faces are square with the bonnet flange on the body.

SPARE PARTS:

Under most conditions the only spare parts needed for a gate valve would be stem packing and bonnet gasket. Under rigorous service stems, gates and seat rings should be carried as spare parts as well as stem packing and bonnet gaskets.

* These items refer to the maintenance of gate valves with standard packing. Where "O" ring packing is used, items (b) and (c) can be disregarded. Damaged "O" rings can be replaced using the procedure outlined in items (d) and (e).

ENGINEERING STANDARD

# INSTALLATION, OPERATION & MAINTENANCE OF HYDRANTS

This standard is issued as a recommendation to the customer for the proper use of fire hydrants.

## INSTALLATION:

(a) When hydrants are received they should be handled carefully to avoid breakage and damage to flanges. Keep hydrants closed until they are installed. Protect stored hydrants from the elements if possible.

(b) Before installation of hydrants clean piping and base and drain ring of hydrant of any foreign material.

(c) When the hydrant is set in position and attached to the lateral, it is good practice to brace the side of the base opposite the inlet to oppose the stress due to pressure tending to force the hydrant off the end of the lateral.

(d) It is recommended practice to install an auxiliary or secondary gate valve in the lateral between the hydrant and the main to permit inspection and repair of hydrant without shutting down mains.

(e) When hydrant drainage is desired to prevent freezing, excavate around the hydrant drain ring and surround the base of the hydrant with crushed stone to a level about five inches above the lower barrel flange. The stone filled area should contain a volume of water at least twice that held by the hydrant barrel.

(f) Both drainage stone and earth fill above the stone should be tamped to give firm support to the hydrant barrel.

(g) Hydrant should be located to give minimum hazard to traffic. Place hydrant back from the curb line to prevent damage to or from overhanging vehicles. On main thoroughfares place hydrants far enough from intersections to avoid damage from accidents. Place hydrants so they are readily visible and accessible. It is suggested that hydrants be painted with reflective paint or marked with reflective tape to permit easy identification at night.

(h) When first installed the hydrant should be operated from full closed to full open position and back to make sure no obstructions are present.

(i) After the hydrant is installed and the line, as well as the hydrant, have been hydrostatically tested, the hydrant should be flushed and then checked for proper drainage.

OPERATION:

The modern hydrant is designed to be opened and closed without the use of "cheaters". Excessive leverage may damage the hydrant, therefore:-

(a) Check direction of opening as marked on the hydrant cover.

(b) To OPEN turn the operating nut until the valve hits the stop in the opening direction. DO NOT FORCE THE HYDRANT IN THE OPENING DIRECTION BEYOND FULL OPEN AS indicated by sudden resistance to turning. If water does not flow when the hydrant is open, it is probably due to a closed valve upstream from the hydrant.

(c) To CLOSE turn the operating nut until the valve closes off the flow. It is NOT NECESSARY TO CLOSE this style of hydrant WITH GREAT FORCE. Once the flow has stopped loosen the operating nut in the opening direction to take the strain off the operating parts of the hydrant and to make it easier to open the hydrant when again needed.

(d) Fire Hydrants are NOT a throttling device and, therefore, are to be operated either in the fully OPEN or fully CLOSED position.

INSPECTION:

(a) It is recommended that hydrants be inspected twice a year, spring and fall. After each use in extremely cold weather hydrants should be inspected.

(b) Inspection should cover the following points:-

b1 External inspection - paint, caps, chains, etc.

b2 Valve leakage - aquaphone check.

b3 Hydrant, drain & nozzle leakage - pressure test of entire hydrant.

b4 Hydrant drainage

b5 Operation from full close to full open and reclose.

MAINTENANCE:

(a) At times of inspection add #1 graphite grease or cup grease at the grease fitting in the top of the operating nut. Do not use excessive greasing pressure on the gun in order to prevent hard operation. Also grease nozzle cap threads with #1 graphite grease.

(b) REMOVAL OF INTERNAL PARTS:

b1 Shut off water in line leading to hydrant.

b2 Open hydrant valve.

b3 Remove bolts and nuts from top flange.

b4 Take off domed cover.

b5 Remove operating head by continuing to turn in the open direction until the thread is turned out of the operating unit. Then carefully strip the head up over the threads.

b6 Place the seat wrench over the rod making sure the square hole in the seat wrench engages the rod square. Turn to LEFT or COUNTERCLOCKWISE to unscrew main valve and drain assembly from the main valve seat drain ring.

b7 Remove seat wrench.

b8 Lift out hydrant rod and all working parts for inspection or repair.

b9 When a new valve ball leather or rubber is installed, it is necessary to install a new lead gasket between the valve ball bottom and the lock nuts to prevent leakage thru the valve ball.

(c) At time of inspection flush out the hydrant lead and hydrant itself. If necessary flush the drains by filling the hydrant and then opening the main valve two turns to force water out of the drains under pressure. The drain valve is open during the first three turns of the operating nut.

# FIELD SAFETY PROCEDURES

Ray Norton

Division of Plant Operations

## SAFETY DURING MAINTENANCE OF DISTRIBUTION SYSTEMS

Due to the many different types of jobs that require doing in maintaining a water distribution system, it is not possible to set up a safety programme by one set of safety standards. The safety programme must be designed to the job, in general, and yet be flexible enough to cover any special type of work including all hazards. This would mean that your safety programme would be based on existing safety regulations, such as the Department of Labour Industrial Safety Act (Reg. 196/64), the Trench Excavators Protection Act (Reg. 559), the Construction Safety Act (Reg. 170/62), good housekeeping and common sense.

It would be appropriate, I think, to examine each of the subjects mentioned to see how they can be applied for the development of a safety programme.

## INDUSTRIAL SAFETY ACT (Reg. 196/64)

Section 11: (Every employer shall ensure that) - (a) every opening place or thing that is likely to be a source of danger to any person is securely fenced or guarded.

Section 12-(1) No confined space referred to in this section shall be tested by any person other than a competent person.

12-(2) (Every employer shall ensure that) any tank, vat, chamber, pit, pipe, flue, or other confined space that may be entered by any person,

(a) has suitable manhole or other means of easy egress from all accessible parts of the confined space and,

(b) is safe for entry.

## TRENCH EXCAVATORS PROTECTION ACT (Reg. 559)

Section 1 (a) Subject to Section 2, this Act and the regulations apply to every trench, including any trench of the Crown or of any agency of the Crown or of any municipality as defined in the Department of Municipal Affairs Act. 1965.

Section 2: This Act does not apply,

(a) to any part of a trench four feet or less in depth.

(b) to a trench where the work therein is done only by the owner thereof in person.

(c) to a trench into which no person is required to enter for any purpose.

(d) to a part of a trench excavated for a pipeline or conduit by mechanical means and the pipe or conduit is prefitted before laying and the trench is mechanically backfilled.

## CONSTRUCTION SAFETY ACT (Reg. 170/62)

This Act is applied to the construction of buildings, but does contain certain sections that cover trenching, laying of pipe and backfilling by mechanical means. The real backbone of a safety programme is of course how the aforementioned Acts are used in conjunction with the experience gained by doing the work every day. Now then, let us put these two factors together and see what kind of a safety programme we can develop out of it.

## TO GAS OR NOT TO GAS THAT IS THE QUESTION

Street manholes, meter pits and valve chambers or any other below ground locations five feet or more in depth. Experience tells us that any of these below ground locations can harbour a number of hazards, i.e. dangerous gases, lack of oxygen, projecting valve stems, slippery floors and sometimes cold, dark water from ankle deep to waist deep that was not there the last time you were down there. Or, perhaps, a combination of two or more of these hazards are present.

The Department of Labour Industrial Safety Act says that these holes are considered confined spaces and, therefore, must be checked out before entering. This does not mean that you need a truck load of testing equipment, but it does mean you must be sure it is safe for entry.

When it is not possible to see the bottom due to depth or darkness, or if the light from your flashlight is reflected back to you, a simple act like dropping a stone down into the opening will confirm if there is water or not. Dropping a stone will also tell you approximately how deep the water may be.

In some areas throughout the Province, dangerous gases are present in the ground water table. Or, as already mentioned, decaying vegetation in the water supply will cause gases to be present in water. In any case, if it is known that gases are in the water table in your area, or if at any time unusual odours are noticed at the entrance to any opening to below ground locations, do not enter it without first checking the air conditions in the manhole or pit. I know it is the practice with some operators to tie a lighted candle on the end of a string and lower it down to check the amount of oxygen present. This is not in the best interest for the safety of those present. If there were explosive gases at the right proportion to air in the manhole or pit, you would have instant clean out, and you might have to replace some equipment, even a man or two as well.

Should the hole or pit have a deficiency of oxygen, say of 12% to 14% instead of 21%, it is doubtful if the candle would go out for some time, if at all. However, at such a level of oxygen a man would not be able to stay in there without breathing equipment, or be able to come back up the ladder without help, even if he returned immediately.

If the gas present was Hydrogen Sulfide $H_2S$ in light concentrations, due to its toxicity the operator would soon find it difficult to move around and would suffer the effects of it for several days. How then should we test for these conditions. For oxygen deficiency a drager meter with oxygen tubes will give you a reading of oxygen present. An explosion meter will tell you if there is an explosive mixture of gas to air present. It will not tell you what kind of gas is present.

It is not always possible to get or have both a drager type meter and an explosion meter, but if an explosion meter can be obtained, it can be used for both oxygen and gas accumulation.

The OWRC operators, when using the explosion meter, will not enter any confined space when the meter hand registers .2%. This is way below any explosive range, but indicates the presence of some kind of explosive gas that could cause a low oxygen level.

When these foregoing conditions prevail, there are two ways to safely enter the manhole or pit. Use a self-contained breathing unit to enter the space if for only a short stay. When it is necessary to remain in the space for a longer time the space must be ventilated. This can be done by using a portable exhaust or suction fan of 550 C.F.M.

For deep spaces a length of 4-inch stove pipe or even a length of down pipe from an eavestrough suspended down close to the bottom of the space and leading into the exhaust fan will clear the air very quickly. When gas is noticed at the entrance do not use any kind of canister mask for protection; they are limited to the concentration of gas present and are no protection against oxygen deficiency.

At all times when entering any manhole or pit a parachute type safety harness and rope must be worn when it has been necessary to vent the space, and must be available at all other times in the event that a rescue may be required. Two or more men must be stationed at the entrance keeping the man or men in the space under surveillance and to be ready to effect any needed rescue procedures.

Not all rescue proceedings will be from the effects of gases or low oxygen. A man can slip on the slippery floor damaging a knee or arm or by falling on to the extended valve stem striking his head, and from these injuries be unable to climb up the ladder unaided.

When it is necessary to use your truck as a road block, and you have to keep your motor running for radio operation, remember not to park it too close to the entrance to any manhole or pit and down wind whenever possible. This would apply to open trenches as well.

ROAD BLOCKING AND TRAFFIC SIGNALLING

Setting up barricades to divert traffic around the work area is not just standing a barricade on either side of the jobsite and letting the car drivers decide for themselves where to go from there. It is placing the barricades far enough up the road that oncoming traffic is eased into the other lane or to the left or right, and it must be visible to the drivers a good distance beyond that point. The Department of Highways are using plastic cones instead of barricades. They are easily seen and if struck by a car they do not become a dangerous flying object. They are very portable and can be stacked in a small space. The use of wooden barricades, with blinking lights, are recommended for complete street or road blockage. In placing barricades on a street, the people using the sidewalk must be considered. You may be well protected from traffic hazards but find some unwary pedestrian has suddenly joined the crew, in the bottom of a trench. The use of flagmen are really a must on any busy street or road, but they must have some training in directing traffic and handling their signs or flags. A flagman must be on his toes particularly during a rain or snow storm and even more so when its foggy.

REPAIRING BROKEN MAINS

This type of repair, in most cases, is done by hand and, because of the speed at which the repair crew works, natural hazards that are present are sometimes overlooked until something happens.

Breaks in water mains are always a challenge to the crew and getting to the break area it sometimes is necessary to use air hammers to break through the pavement. The man on the hammer may break into a high tension cable or a phone cable. The foreman on the job should know or have on hand a blueprint of the main cables laid in the streets. Accidents can occur while pouring lead joints in pipes, making cuts with a chisel or a diamond point. These hazards point up to the necessity of wearing safety equipment, such as eye goggles, while chipping etc., heavy gloves while leading and a hard hat particularly while below grade level. Remember the ground around a water main break becomes saturated and unstable, sometimes completely washed out. The work of uncovering the broken main under such circumstances must proceed at a slower rate.

The subjects mentioned up to this point have not covered all of the hazards or hazardous places or things that can be encountered in distribution system maintenance and repairs. There are many more, such as truck driving, unloading heavy pipe, lowering pipe into a trench, being familiar with trench shoring and ground conditions and others.

## SUMMARY

In summing up this session, what factors have we brought out to help us to set up a safety programme? First of all, we would put down all the safety regulations by the various governmental departments related to this type of work. A plan of action should be drawn up on procedures before the work is started, during the work, and after the job is done, whether the job is routine or an emergency.

One way to ensure that the men think "safety" is never to let the subject drop or assume that everybody knows all about it. Hold safety sessions in the shanty, or a tailgate conference. Don't leave any workman or group alone too long; appoint someone to check the safety equipment and to be responsible for having it at the job site. When your barricades, warning signs and flags are in their proper position, and the flagman knows his job, you are not only protecting the men working in the area, but you are also protecting the municipal city or P.U.C. you work for from possible lawsuits.

# PLANS & RECORDS

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## INTRODUCTION

This paper will deal with "Plans and Records" pertinent to you as one of the Operating Staff in your Utility. No Water Utility can operate efficiently without a well maintained permanent record system. No Operating Personnel can work effectively if he does not understand the Plan and Records System.

Efficient operation of a distribution system requires that the superintendent or manager, have before him an accurate picture of the whole system he operates. A "Comprehensive Map" or "Operating Map" will enable him to determine which areas are inadequately supplied and why, whether the mains in an area are capable of supplying the water which might be required to fight a major fire, if fire hydrants are improperly spaced, where trouble should be looked for when pressures are found to be below normal and to determine new feeder main routes.

The operating staff in their daily operation of the water system require records that show in proper detail the location and valving for existing and future systems. This map should show the size of all mains active or inactive, their location, valves and fire hydrants shown and numbered, and any other operating information. This type of record is called a "Section Map".

Additional records are still required by the Operating Staff. They should have small sized maps showing the layout of the distribution mains. As part of their equipment, complete sets of valve measurements covering the districts in which they work are necessary if valuable time is to be saved in making valve closures. Residential services and their curb stop locations can be recorded in a book form and copies kept with each crew. Large size services (over 3/4" dia.) can be kept in book form, but here the route, size and materials are recorded.

Other records such as the following are kept in the office. These are valve records, hydrant records, records of leaks and main breaks, as constructed work order drawings, inspector's reports (new watermain construction), photographs.

No matter what size your Utility may be, record keeping is a time consuming chore. Your Engineering Department must be responsible for the large maps to be brought up to date accurately, but you people can relieve the chore by filling out your field forms and records neatly and accurately so they will form the permanent records themselves. Use still cameras to record an installation, e.g. "Polaroid" Cameras. Valve and hydrant field maintenance sheets can be stapled to their respective cards. Why spend time transferring information? You've got it down once and correct, use it that way.

Each Utility should prepare a "standard practice" to apply to its own procedure of keeping distribution system records. All phases of record keeping should be enumerated and described so that anyone in the organization can, by referring to the standard practice, know how to prepare, find or interpret any of the distribution system records.

The following is a suggested format of permanent maps and records suggested for use in the Water Industry.

## SYMBOLS

The need for some degree of standardization of symbols used on mapped distribution system records is desirable. Each mapped record tells a story which could be made clearer, if the language used was based upon an alphabet familiar to a person endeavouring to read the record.

Standardization of symbols between Utilities need not be, only that your symbols be simple in design, easily drafted, and their function understood.

The symbols shown in page 3 are suggested as a guide to be followed on various types of mapped records. The symbols shown are those from the A. W. W. A. M8 Distribution Manual. The sample maps in this paper have symbols that were adopted by the Oakville Public Utilities Commission.

L - 3



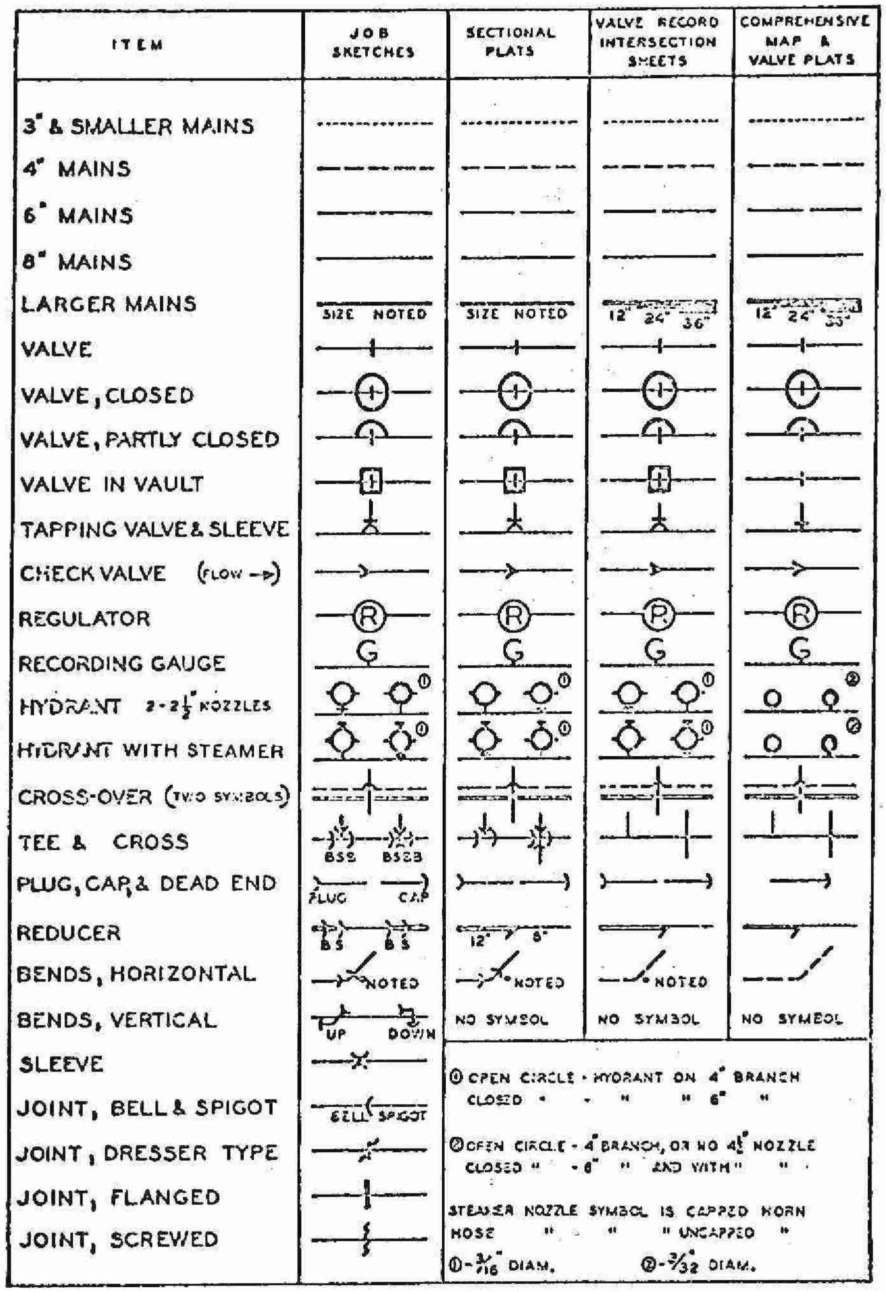



FIG. 18. Symbols

## MAPPED RECORDS

Details on drafting techniques, types of tracing paper, ink, lead pencil will not be dwelled upon, since your Engineering Group will have skilled personnel to handle this part. Your concern is to have the up-to-date copies, know what they represent, how to use them and mark them up when required.

## COMPREHENSIVE MAP or OPERATING MAP

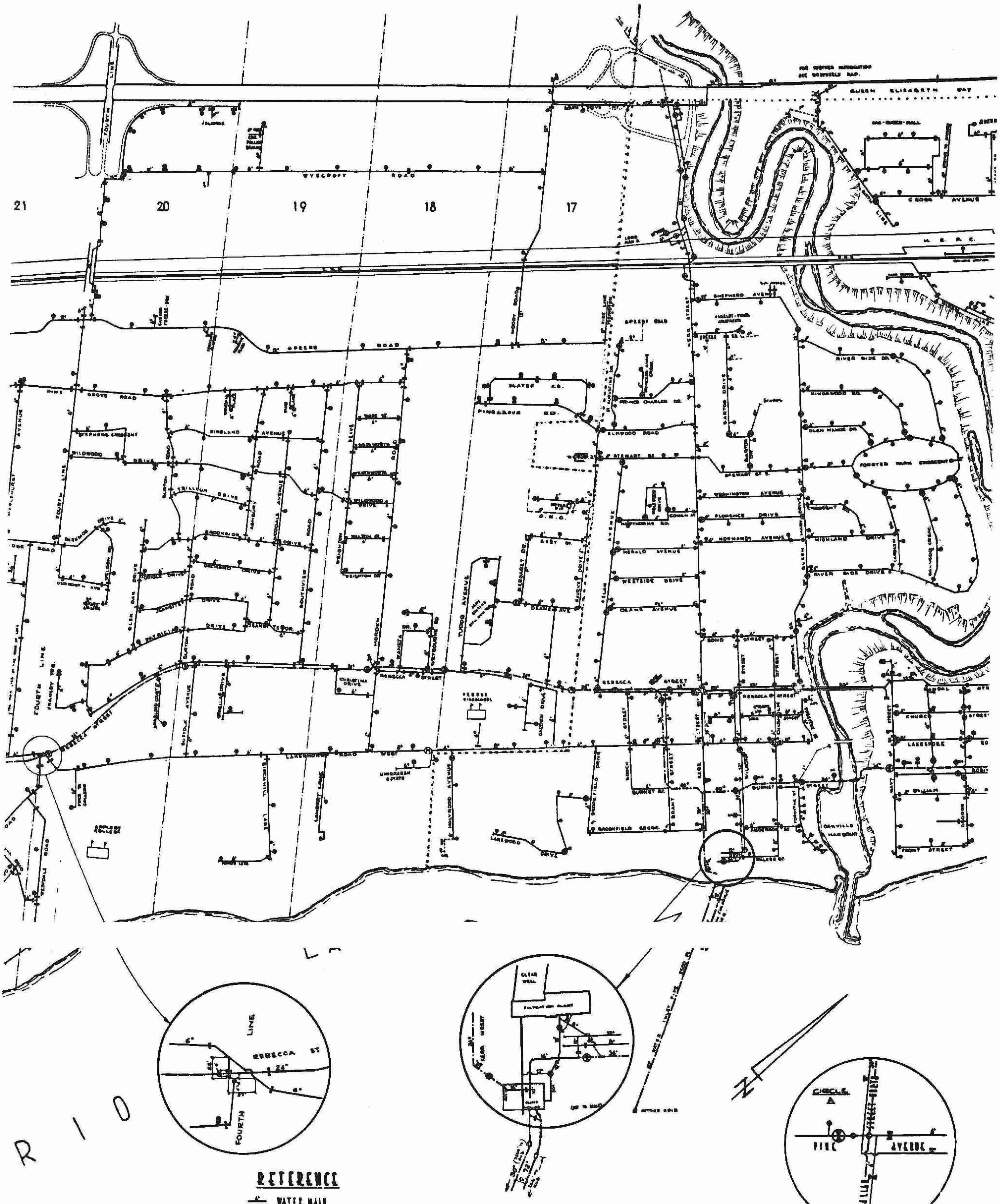
The function of this record is to show a clear picture of the entire water distribution system in diagramatic layout. It is primarily an operating record of value to the superintendent and construction engineer. It should be drawn in such fashion as to indicate readily the areas adequately piped, the sections which suffer through lack of large mains, the place where short extensions will eliminate dead ends, where many fire hydrants are installed in congested districts, but where mains are inadequate to support them in case of a major fire. Secondarily, as a record of physical assets.

Since the main function of this record is to form a clear picture of the watermain system, all distracting information is omitted. Street or property lines should be deleted, - cut down on confusion of lines. Insignificant items should be left out. Line thickness should be employed to represent different main sizes so that the larger mains with greater carrying capacity will be easily spotted. Important connections at intersections can be shown diagrammatically at a larger scale.

The scale should be as large as possible, using a map preferably 42 in. wide (standard roll width). A scale of 1" = 400 ft. was found to be convenient in our Commission. Scales somewhat smaller e.g. 1" = 800 ft. or 1" = 1,000 ft. requires very careful drafting.

The "Operating Map" should be used, put in your map tacks, colour in areas, show changes in red pencil. Don't let this map become a showpiece pasted on a wall. It was meant to be used by you.

Page 5 shows a portion of a Comprehensive Map or Operating Map.




**REFERENCE**

- WATER MAIN
- GATE VALVES
- HYDRANT
- BLOW-OFF VALVE
- METER CHAMBER

THE OAKVILLE PUBLIC UTILITIES COMMISSION
PORTION OF "COMPREHENSIVE MAP"

DATA RELATING TO A COMPREHENSIVE MAP

| | | |
|---|---|---|
| Material | Original - Heavy Tracing Cloth or Mylar Film | |
| | Prints - | Black or Blue Line |
| Scale | 1" = 400 ft | (Note - this map from microfilmed copy at reduced scale) |
| Items to be shown on Map | Street Names, Main Size, Hydrants, Valves | |
| | North Arrow, Scale, Last Date Corrected. | |

A brief note on this map is that it has been micro filmed, then reproduced on tracing paper at a reduced scale eg. 1" = 1,000 ft. (approximately). The original is 42" wide by 7ft. long.

## SECTION MAPS

This record should be considered as the complete mapped record of the distribution system structures. It is the detail account of the distribution system assets. Since it must be at much larger scale than the comprehensive or operating map, this record must usually be in sections, hence the term.

The comprehensive map should be used as the base for the "section map", North-South and East-West coordinates should be drawn on a print of the comprehensive map corresponding to the size of 100 ft. scale "section map". The spaces should be numbered like a road map eg. 1,2,3, etc. from North to South and lettered A,B,C, etc. from East to West. Avoid overlaps, section off an area where the boundaries cut between streets, not down a street.

Each section map should butt up against the next.

Copies of these maps should be made up in a book form. Here again the copies are meant to be used; additions and corrections by both the operating staff and engineering department should be made in some contrasting colour as work reports are completed.

Page 8 shows a "section map" at a reduced scale. This map was formed from microfilmed records to the size illustrated. Copies of these maps are in a book form and are part of the tools in each vehicle in our Commission.

Data relating to a "Section Map"

Material: Original - heavy tracing cloth or Mylar Prints - Prints - Black or Blue Line

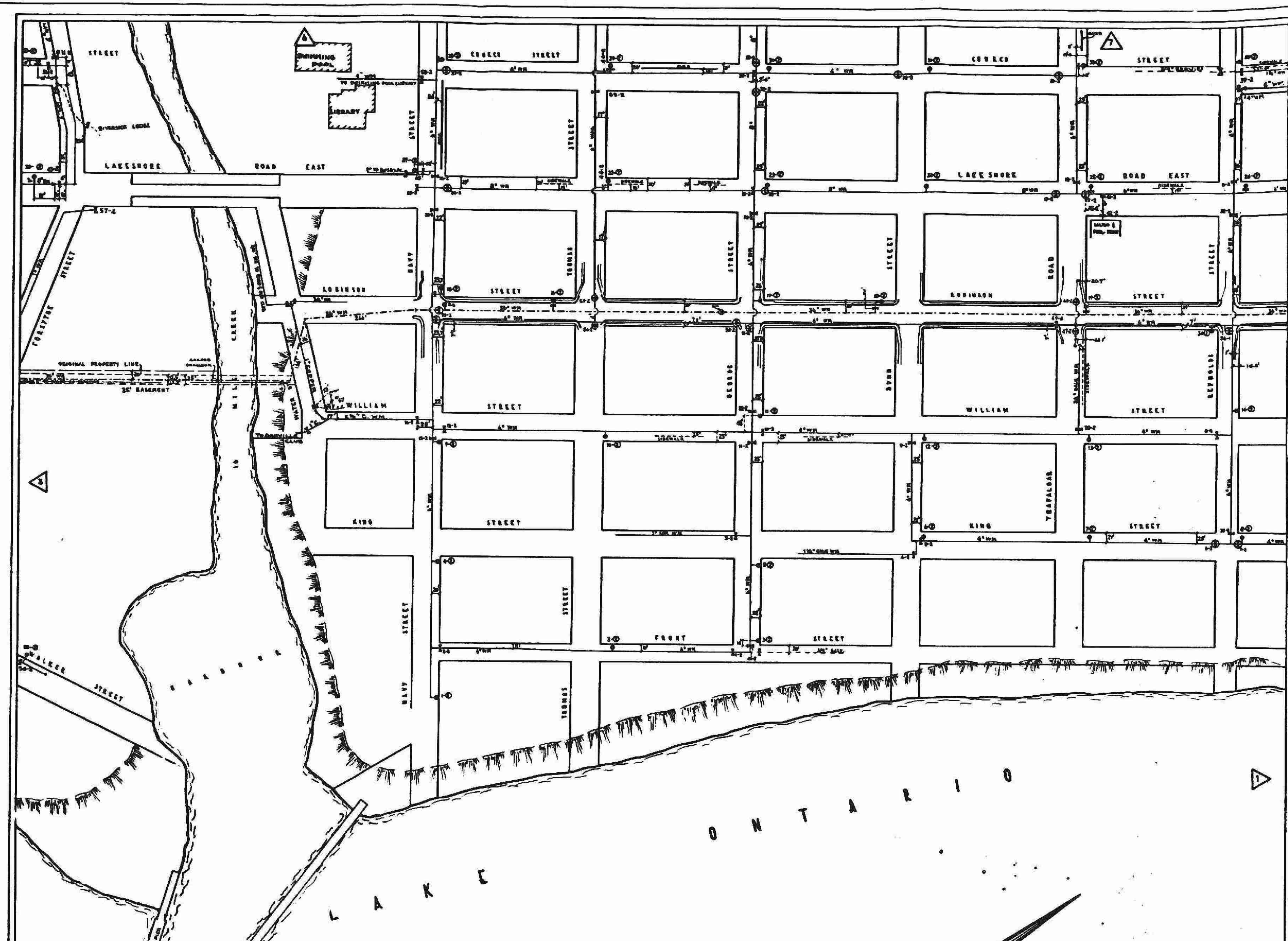
Size of Maps: 22" x 34" (automotive industry standard) able to be folded into 8.1/2" x 11" size - standard letter size.

<u>Scale:</u> 1" = 50 ft. in congested areas
1" = 100 ft. in residential areas
1" = 200 ft. in rural areas

<u>Index:</u> Co-ordinates; horizontal spaces lettered, vertical spaces numbered

<u>Items to be Shown on "Section Maps"</u>

1. Map designation or number
2. Adjacent Map Numbers
3. Street Names and Width
4. Mains and Sizes
5. Material to Main
6. Years Mains were Installed
7. Work Orders of Main Installations
8. Distance from Property Line.
9. Fire Hydrants, Numbers and Classifications
10. Valves and Numbers
11. Valve Sheet designation shown in margin
12. Intersection numbers (if valve intersection maps are used)
13. Block Numbers
14. Lot Numbers
15. House Numbers
16. Water Account Numbers
17. Measurements to Service Lines
18. Sizes of Taps




THE OAKVILLE PUBLIC UTILITIES COMMISSION
- "Section Map"
- Note: This copy from microfilmed records & reproduced at this scale
- Normal scale 1" = 100 ft. on a 25" x 33" sheet

19. Size and Materials of Service Lines

20. Distances, Main to Curb Stop

21. Distances, Curb Stop to Property Line or Building

22. Distances, to angle points

23. Distances, to fittings

24. Dead Ends and Measurements

25. Last Revision Date

26. North Arrow

27. Scale

## VALVE RECORD:

Valves play such an important part in the operation of a distribution system that a separate record of them is warranted. To be of greatest value, this record should be kept in a manner which will allow copies to be carried by the operating staff. This record must show measurements from permanent reference points to each valve so that it may be readily located. The record should also give current factual information about each valve, eg. the direction to open; the make, and date installed.

Several satisfactory methods of keeping these valve records are used by Water Utilities. Two of the common ones are as follows:

1. "Map and List" Record
2. "Inter Section Sheet"

### "Map and List" Record

Each map shows a section of the distribution system at a scale of 1" = 500 ft. covering an area 4,000 ft. x 5,000 ft. on a 10" x 14" sheet. This would be the same area as shown on four of the sectional maps described earlier.

On an intersection map are shown the street names, mains and their sizes, valves with numbers, and hydrants. On an opposite page or pages is shown the valve information; valve number; principal street with reference measurements to property line or street centre line or curb, intersecting street with reference measurements to property lines or centre line or curb, size and make of valve, direction of operation.

Where an intersection has complicated detail a large scale map supplement may be drafted and properly referenced.

Index for "Valve Map and List Record" should follow the format used for "Section Maps".

This type of record gives the operating staff all the essential valve information and also shows how the mains are tied in. Its thickness is but a fraction of an intersection book.

Here again, corrections and additions should be shown in contrasting colours on copies of these records.

Page 11 shows a typical layout for such a record. These examples are copies from the A.W.W.A. M8 Distribution Manual.

## "Intersection Sheet" Record

This system requires the drawing of intersection maps on which mains, valve, hydrants, etc. are shown. These maps are at such a scale that dimensions to permanent reference points, preferably property lines or street lines, can be given. The scale should be either 1" = 20 ft. or 1" = 30 ft. Valves between intersections cannot be shown to scale but dimensions from intersecting streets should be given to locate such out of scale items.

Indexing such a record can follow a number of methods. One method is to relate the intersection sheet with the sectional map. Another is to list the intersections alphabetically and suffixed with a number. Use the first letter of the name for the East-West Street then followed by a number. Of course, a cross referenced index, should be included with each intersection book.

L - 11

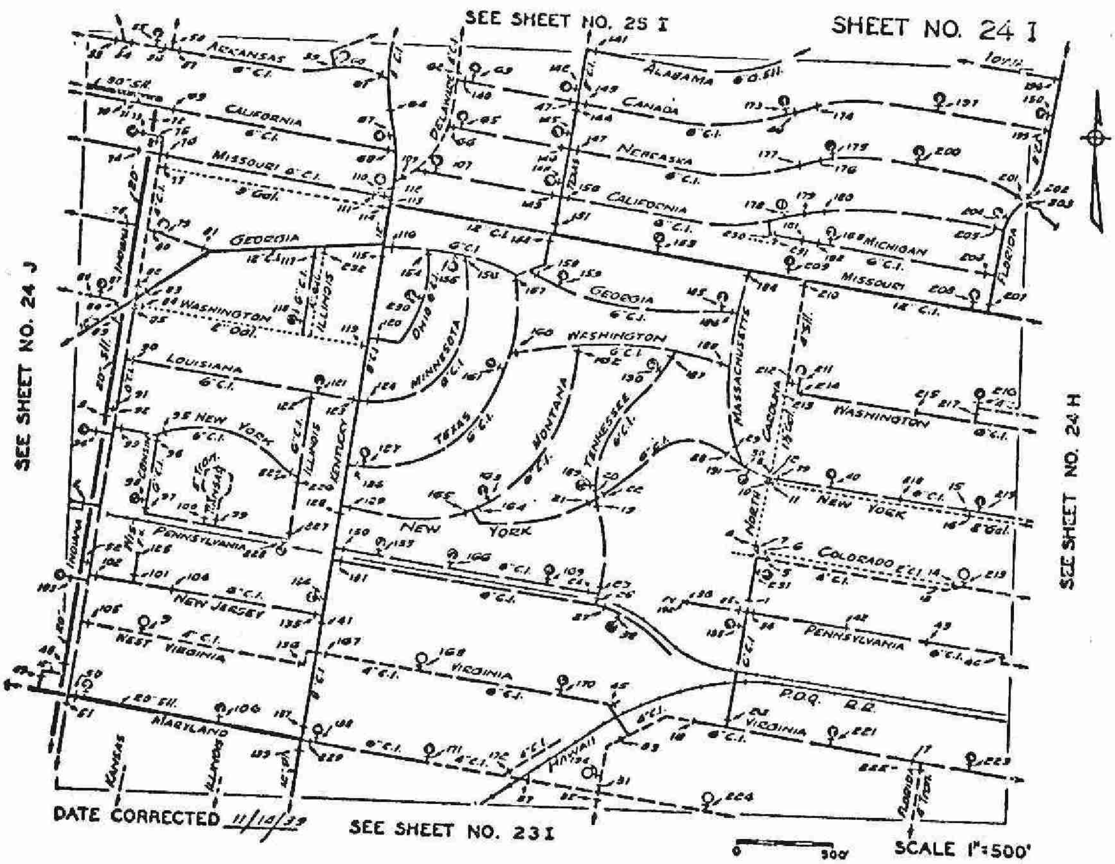



Fig. 4. Valve Plat

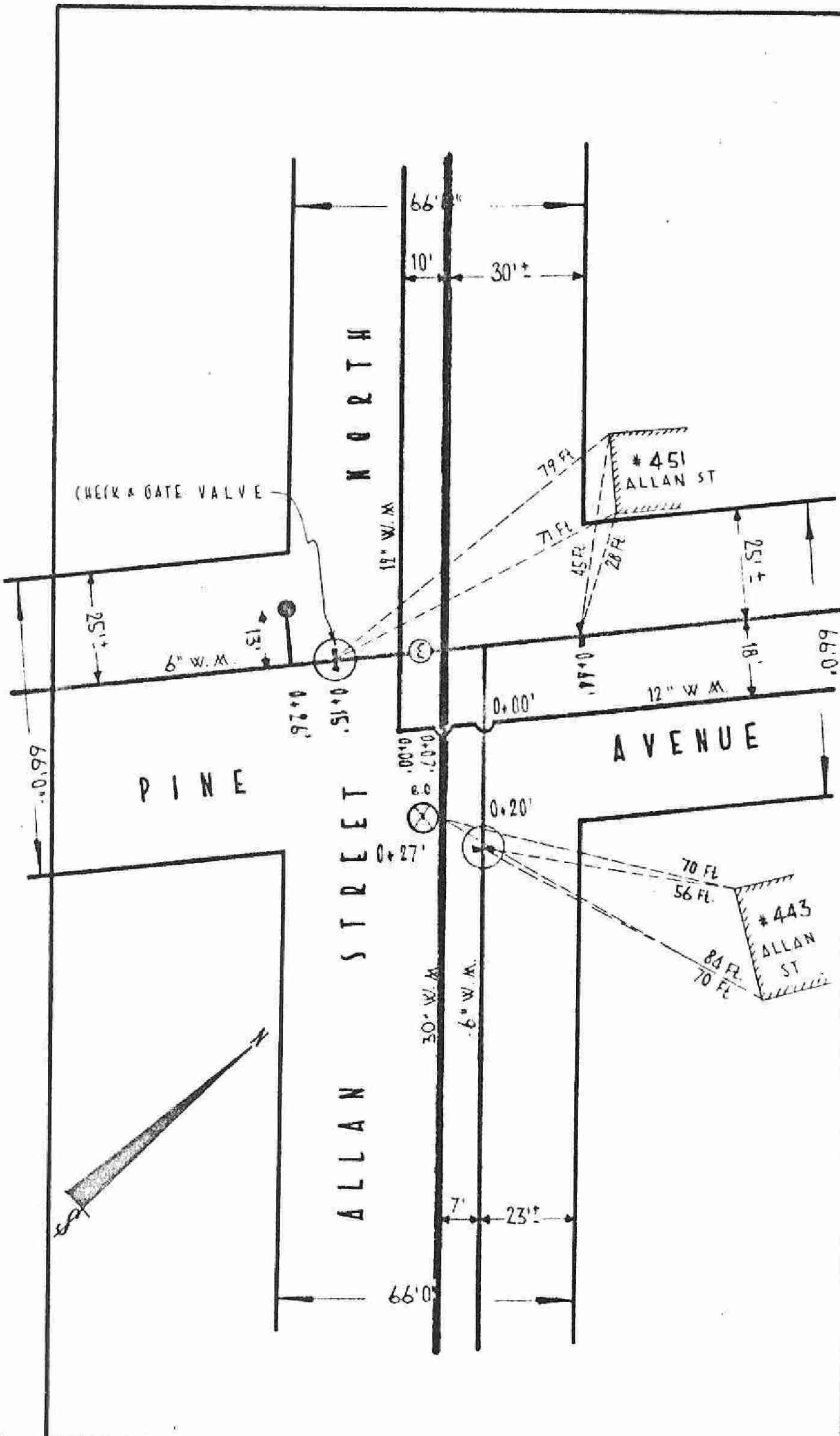
SHEET NO. 24 I

| Valve No. | Principal Street | Distance Ft. | Dir. | Reference | Intersecting Street | Distance Ft. | Dir. | Reference | Size | Make | Open | Turns | Date Set | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | North Carolina | 11 | W | E.side E.walk | Pennsylvania | 12 | N | N.side N.walk | 6 | A.P.S. | L | 13 | 5/22 | |
| 2 | Pennsylvania | 1½ | S | N.R. | Indiana | 18 | E | W.R. | 6 | A.P.S. | L | 16 | 7/33 | Pal. Tap |
| 3 | Indiana | 6½ | S | N.R. | New York | 22½ | N | N.R. | 20 | [illegible] | L | 62 | 1/31 | |
| 4 | North Carolina | 11 | W | E.side E.walk | Colorado | 5 | N | N.side N.walk | 2 | A.P.S. | - | T.Hd. | 9/12 | |
| 5 | Colorado | 12 | N | S.side S.walk | North Carolina | 3 | E | of E.side E.walk | 2 | Cha. | L | 9 | 5/22 | |
| 6 | Colorado | 22 | S | N.side N.walk | North Carolina | 11 | W | E.side E.walk | 2 | Cha. | - | T.Hd. | 5/12 | |
| 7 | Colorado | 22 | S | N.side N.walk | North Carolina | 12½ | W | E.side E.walk | 2 | Cha. | - | T.Hd | 9/12 | |
| 8 | New York | 3½ | S | N.side N.walk | North Carolina | 15½ | W | S.R. priv. Rd. | 2 | F&C | - | T.Hd. | 10/12 | |
| 9 | West Virginia | 7½ | S | N.side N.walk | Indiana | 27½ | E | W.R. 7615 | 6 | F&C | L | 13 | 10/15 | 8' S.W. of Hydrant |
| 10 | New York | 15½ | S | S.side S.walk | North Carolina | 11½ | W | of E.side E.walk | 2 | Mue. | - | T.Hd | 2/13 | |
| 11 | New York | 15½ | S | S.side S.walk | North Carolina | 5½ | W | E.side E.walk | 2 | [illegible] | - | T.Hd | 10/22 | |
| 12 | North Carolina | 15½ | W | E.side E.walk | New York | 10½ | N | S.side S.walk | 2 | Eddy | - | T.Hd | 9/12 | |
| 13 | Colorado | 22½ | S | N.side N.walk | Florida | 5½ | W | E.side E.walk | 4 | Ohio | L | 11 | 3/14 | |
| 14 | Colorado | 11 | N | S.side S.walk | Florida | 8½ | W | W.side W.walk | 4 | Ohio | L | 12 | 3/14 | |
| 15 | New York | 10 | S | N.R. | Florida | 14 | W | W.R. | 6 | Ren. | L | 15½ | 3/35 | Pal. Tap |
| 16 | New York | 10½ | S | S.side S.walk | Florida | 9½ | W | E.side E.walk | 2 | Ohio | - | T.Hd | 10/22 | |
| 17 | Virginia | 2½ | S | N.side N.walk | Florida | 23½ | W | W.side W.walk | 6 | Fair | L | 12 | 5/15 | |
| 18 | Virginia | 8 | N | S.side S.walk | North Carolina | 3½ | W | [illegible] | 6 | Fair | L | 15½ | 11/23 | |
| 19 | Tennessee | 7½ | E | W.side W.walk | New York | 5½ | N | N.side N.curb | 8 | Fair | L | 23 | 11/23 | |
| 20 | Tennessee | 7½ | E | W.side W.walk | New York | 6 | N | N.side N.walk | 6 | [illegible] | L | 18½ | 11/23 | |
| 21 | New York | 2 | S | N.side N.walk | Tennessee | 5½ | E | E.side W.curb | 8 | [illegible] | L | 22 | 11/23 | |
| 22 | New York | 6½ | S | N.side N.walk | Tennessee | 12½ | W | W.side E.curb | 8 | [illegible] | L | 22 | 11/23 | |
| 23 | Tennessee | 2 | E | W.R. | Pennsylvania | 3 | N | N.R. | 6 | Lud | L | 25 | 4/25 | in Vault |
| 24 | Pennsylvania | 7 | S | N.R. | Tennessee | 2 | E | W.R. | 6 | Lud | L | 23 | 4/25 | |
| 25 | Tennessee | 3 | W | W.R. | Pennsylvania | 7 | S | N.R. | 6 | Lud | L | 23 | 5/25 | |
| 26 | Virginia | 1½ | N | N.curb | Drive & W. Virginia | 5 | W | E. | 8 | Eddy | L | 20 | 7/27 | |
| 27 | Pennsylvania | 10 | N | S.R. | Tennessee | 12 | E | W.R. | 6 | Eddy | L | 20 | 5/27 | |
| 28 | New York | 7 | S | N.side N.walk | Massachusetts | 60½ | W | W.side W.walk | 3 | Vogt | L | 13 | 11/23 | |
| 29 | Massachusetts | 13 | E | W.side W.walk | New York | 26 | N | N side N.walk | 3 | Vogt | L | 13 | 11/23 | |
| 30 | New York | 20 | N | S.curb of park | Massachusetts | 8½ | E | W.curb park | 3 | Vogt | L | 13½ | 11/23 | |
| 31 | Hawaii | 9 | E | W.curb | Maryland | 47 | N | S.curb | 4 | [illegible] | L | 12 | 12/14 | |
| 32 | Bowie Drive | 40 | E | W.curb Hawaii | Maryland | 4 | S | S.curb | 4 | Ford | L | 13 | 1/25 | |
| 33 | Virginia | 4½ | S | S.curb | Hawaii | 323 | S | S.curb | 4 | Ford | L | 13 | 1/25 | |
| 34 | Pennsylvania | 4½ | S | S.side N.walk | North Carolina | 5 | E | E.edge E.walk | 4 | [illegible] | L | 13½ | 3/31 | |
| 35 | Pennsylvania | 12 | S | N.R. | North Carolina | 10 | W | W.R. | 4 | [illegible] | L | 12½ | 3/31 | |
| 36 | Pennsylvania | 12 | S | N.R. | North Carolina | 155 | W | W.R. | 6 | R&S. | L | 21 | 3/32 | |
| 37 | Maryland | 54 | N | S.side S.walk | P.D.Q. R.R. | 25 | S | S.rail | 4 | [illegible] | L | 10 | 12/10 | |
| 38 | Pennsylvania | 2 | N | S.R. | Tennessee | 22½ | E | E.R. | 6 | Fair | L | 15½ | 10/33 | 12' W. of Hydrant |
| 39 | New York | 22 | S | N.R. | North Carolina | 11 | E | E.R. | 6 | [illegible] | L | 13½ | 3/35 | |
| 40 | New York | 23 | S | N.R. | North Carolina | [illegible] | E | E.R. | 6 | Ren. | L | 27½ | 2/35 | 2' N. of Hydrant |
| 41 | Kentucky | 10 | E | N.R. | New Jersey | 15 | S | S.R. | 8 | A.P.S. | R | 27 | 4/26 | Note: Opens Right |
| 42 | Pennsylvania | 12 | S | N.R. | Florida | 617 | W | W.R. | 3 | Ren. | L | 10½ | 5/35 | |
| 43 | Pennsylvania | 4½ | S | S.edge N.walk | Florida | 14 | E | E.edge E.walk | 6 | Ren. | L | 11½ | 5/35 | |
| 44 | Pennsylvania | 2½ | N | N.edge N.walk | Florida | 210 | E | E.edge E.walk | 6 | Ren. | L | 11½ | 6/35 | |
| 45 | Virginia | 29 | S | S.edge N.walk | Hawaii | 51 | E | [illegible] | 6 | [illegible] | L | 13½ | 4/35 | |
| 46 | Canada | 7 | E | N.R. | Vermont | 15 | W | W.R. | 6 | Cha. | L | 10 | 12/25 | |
| 47 | Canada | 7½ | E | N.R. | Texas | 3½ | W | W.R. | 6 | Cha. | L | 13 | 3/17 | |
| 48 | Indiana | 3½ | E | W.side W.walk | Maryland | 7½ | N | N.side N.walk | 20 | [illegible] | L | 59 | 1/31 | |
| 49 | Maryland | 12½ | S | S.side S.walk | Indiana | 1½ | E | W.side W.walk | 12 | [illegible] | L | 35 | 1/31 | Bl. Fose |
| 50 | Maryland | 12½ | S | N.side N.walk | Indiana | 31½ | E | E.side E.walk | 20 | [illegible] | L | 62 | 1/31 | |
| 51 | Indiana | 21½ | E | W.side W.walk | Maryland | 12½ | S | S.side S.walk | 2 | Cra. | L | 13 | 4/29 | |
| 52 | Indiana | 1½ | E | W.R. | Pennsylvania | 21 | S | S.R. | 6 | [illegible] | L | 14 | 4/29 | Bl. Fose |

Fig. 3. Valve List

Note: Four additional valve lists are necessary to show all valves on Plat 24 I.

P15




JAN. 65 / NOV 61

THE OAKVILLE PUBLIC UTILITIES COMMISSION
INTERSECTION SHEET

Use a standard size sheet for intersection sheets 8.1/2" x 11" letter size. Enough detail for an intersection can be compiled on a sheet this size. Smaller sheets will tend to restrict enough legible information.

The big disadvantage of such a record is that it quickly becomes too bulky. The operating staff would tend to find the record awkward to handle in the field.

Page 12 shows a sample intersection sheet as used by the Oakville Public Utilities Commission. You will note that the map proper is not drawn to letter size sheet. We are in the process of converting to a letter size sheet.

## SUPPLEMENTED MAPPED RECORDS

Other maps are maintained in a water works system. These maps are basically for planning purposes. Only to list them will let you know that they exist and are used by the Water Industry.

1. Arterial Map - show primary Distribution Mains
2. Valve Closure Map - Show Valving Weaknesses
3. Leak Survey District Map
4. Water Gradient or Pressure Contour Map
5. Leak Frequency Map.

## CARD RECORDS:

Certain distribution system records are difficult to put in a mapped form; these are usually kept on cards. These are records of individual valves, hydrants, services, etc. , where it is desirable to keep both location, description and historical data for each unit.

This paper will not go into describing the cards since the sample cards appended show clearly the data which should be provided for. Space is allowed on each card for a short statement of the maintenance performed.

A natural inclination will be to show too little original information on these cards. The original time required to list complete data will be only a minute or so longer than it takes to list incomplete data, whereas a few years later it will take hours to obtain data omitted on just a single item. Therefore, each card should have places provided for all the pertinent data. However, certain of the items shown on the cards may be omitted in specific cases. You know your specific needs, design the data list to suit your operation. Pages 16 & 17 show sample cards.

## MAINTENANCE RECORDS:

While a water utility can operate without keeping many records of maintenance work performed, it is usually necessary for the superintendent or manager to report the amount of maintenance work performed to justify the expenditures which are under his supervision.

The sample sheets appended are presented for several of the maintenance operations. Where historical records are kept of valves, hydrants, services, etc., these operation reports should be transcribed or attached to the individual historical cards before the reports are filed.

## REPRODUCTION OF ORIGINAL MAPS AND RECORDS:

In the last decade, new reproducing techniques have been developed and improved.

Records can be microfilmed and from this film any size copy of the record can be produced for a specific need. For security reasons, I suggest you have your records microfilmed. Store the film in a bank vault or fire-proof chamber. Our Commission microfilmed all their plans and records at a cost of 40¢ per frame. This also included a reduced copy of the plans on a 11" x 14" sheet of tracing paper. The reduced size drawings enable us to provide our operating staff with manageable size field copies.

Electrostatic copiers, such as the "Xerox" copier should be employed to make fast and inexpensive copies of records.

White printing machines have been improved to give high quality prints at fast printing speeds.

Instant photographs - eg. "Polaroid Camera" are beneficial to creating records re: intersection sheets, special construction techniques, before and after scenes of construction sites, etc.

These copying techniques have caused a change in the methods and materials used for the original records, eg. using bond paper and pencil lines, in lieu of tracing cloth or mylar and ink lines.

Remember, time is money. Where you can assist in producing fast and accurate records, you will aid the efficient operation of your Utility.

CONCLUSION:

If your Water Utility is without a record system described, I suggest you promote the adoption of such a system now. If your records are not as concise, take action now to bring them up to standard practice. It is fine to rely on the memory of the senior employees in your Utility, but when they are gone, who and what do you turn to when you can't find THAT valve.

References:

(1) A.W.W.A. M8 Distribution Manual "A Training Course in Water Distribution".

A.W.W.A. Incorporated,
2 Park Avenue,
NEW YORK, N.Y. 10016.

(2) Oakville Public Utilities Commission,
OAKVILLE. Ontario.

Oakville P.U.C.

## VALVE RECORD

Intersection Ref. Sheet H-47 No. 5-20A

Location HOLTON HEIGHTS DRIVE 17 Ft. E. Of 8" W.M. HOLTON HTS. DR.

And 17 Ft. N. Of S. P.L. KENSINGTON DR. DRIVE

Size 8" Make DARLING Type GATE Gearing — By-Pass —

Opens 26 Turns to Operate LEFT Set In V/BOX Depth to Nut 4'-6"

Remarks P.U.C. SUBDIVISION FILE S-62-3

CONTRACTOR: BOT CONSTRUCTION - OAKVILLE

### MAINTENANCE AND INSPECTION RECORD

| DATE | WORK DONE | OK | BY | DATE | WORK DONE | OK | BY |
|---|---|---|---|---|---|---|---|
| APRIL/65 | INSTALLATION DATE | ✓ | P.J.L | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
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| | | | | | | | |
| | | | | | | | |

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# HYDRANT RECORD

OAKVILLE P.U.C.

NO. 31-40

LOCATION NADIA PLACE - (NORTH END)

DATE SET OCT. 6/67 MAKE DARLING ~~B-50-B~~ OUTLETS 2-2½" DEPTH OF BURY 5'-6"

SIZE OF: BARREL 9½" VALVE OPENING 6¼" HUB OPENING 6" HYDRANT OPENS L

BRANCH SIZE 6" LENGTH 8'-6" CONNECTS TO 6" MAIN ON NADIA PL.

BRANCH VALVE: MAKE DALING OPENS L TURNS 14 LOCATED 2 FT. W OF HYDRANTS

NORMAL STATIC PRESSURE: 50 P.S.I RESIDUAL PRESSURE: ONE 2½ PORT OPEN —

REMARKS: SUBDIVISION FILE S-67-34

MAINTENANCE AND INSPECTION

| DATE | WORK DONE | OK | BY | DATE | WORK DONE | OK | BY |
|---|---|---|---|---|---|---|---|
| OCT/67 | INSTALLATION DATE | ✓ | T.C.B. | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

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## VALVE MAINTENANCE REPORT

OAKVILLE P.U.C.

INTERSECTION REF. SHEET 576 VALVE NO. 89-49

LOCATION N. E. Corner of Shaw St
& Lees Lane

17 FT. S OF N P.L. OF Shaw St.

17 FT. W OF E P.L. OF Lees Lane.

VALVE TURNS L TO OPEN. NO. OF TURNS 20

FOUND Open OR TURNS CLOSED 20

PACKING: O.K. ✓ TIGHTENED REPLACED

STEM: OK ✓ BENT OR BROKEN No REPLACED

OPERATING NUT OK ✓ MISSING No REPLACED

GEARS: CONDITION None GREASED Nil

BOX ✓ OR VAULT OK ✓ REPLACED

BURIED No IN" PROTRUDING No IN"

TO CLOSE TO STEM No RESET —

COVER: MISSING No BROKEN No REPLACED —

WEDGED IN Yes TARRED OR GROUTED IN Yes

ANY OTHER DEFECTS V/box cleaned of tar and working O.K.

DATE INSPECTED June 16, 1967 BY R. Greene

DEFECTS CORRECTED " "

DATE June 16, 1967 BY R. G.

## HYDRANT MAINTENANCE REPORT

OAKVILLE P.U.C. HYDRANT NO. 2-59

LOCATION S.W. Corner of Marine Dr. & Nelson

CAPS: MISSING No REPLACED ....... GREASED .......

CHAINS: MISSING No REPLACED ....... FREED .......

PAINT: OK ✓ REPAINTED .......

OPER. NUT OK ✓ GREASED ....... REPLACED .......

NOZZLES: OK ✓ CAULKED ....... REPLACED .......

VALVE & SEAT: OK ✓ REPLACED .......

DRAINAGE: OK ✓ WET No DRAINS SEALED .......

PACKING: OK ✓ TIGHTENED ....... REPLACED .......

FLUSHED ✓ MINUTES 2 NOZZLE OPEN Full

PRESSURE: STATIC 60 psi RESIDUAL —

FLOW 250 G.P.M.

BRANCH VALVE: CONDITION No valve.

OTHER DEFECTS This hydrant was raised (2' extension used) "Darling" type hydrant Work Order # W1320

INSPECTED ....... BY .......

DEFECTS CORRECTED Sept. 19, 1969 BY R. Greene & Crew

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# THE OAKVILLE PUBLIC UTILITIES COMMISSION

## WATERMAIN EXPOSURE REPORT

DATE: FEB 22/84.
W.O. No. 69918
BREAK No. 14.
NOTIFIED 12 NOON
OFF 3:45 PM.
ON 5:15 PM

### FIELD DATA FOR MAIN BREAK EVALUATION

STREET Argus Dr. Opposite Car Wash.

TYPE OF MAIN: Cast SIZE 6" JOINT LEAD COVER 5 FT. 6 IN.

THICKNESS AT POINT OF FAILURE — INCH.

NATURE OF BREAK: Circumferential ☑ Longitudinal ☐ Circumferential & Longitudinal ☐ Blowout ☐ Joint ☐

Split at Corporation ☐ Sleeve ☐ Miscellaneous ______ (describe) ☐

APPARENT CAUSE OF BREAK: Water Hammer (surge) ☐ Defective Pipe ☐ Corrosion ☐ Deterioration ☐

Improper Bedding ☑ Excessive Operating Pressure ☐ Differential Settlement ☑ Temp. Change ☐ Contractor ☐ Misc. ______ (describe) ☐

STREET SURFACE: Paved ☐ Unpaved ☑ TRAFFIC: Heavy ☐ Medium ☐ Light ☐

TYPE OF STREET SURFACE Tar & Gravel SIDE OF STREET: Sunny ☑ Shady ☐

TYPE OF SOIL Clay & Rock. RESISTIVITY ______ ohm/cm

ELECTROLYSIS INDICATED: Yes ☐ No ☑ CORROSION: Outside ☐ Inside ☐

CONDITIONS FOUND: Rocks ☑ Voids ☐ PROXIMITY TO OTHER UTILITIES Gas Main 15'E. of W/MAIN

DEPTH OF FROST 12 INCH DEPTH OF SNOW — INCH

### OFFICE DATA FOR MAIN BREAK EVALUATION

WEATHER CONDITIONS: PREVIOUS TWO WEEKS Cold.

SUDDEN CHANGE IN AIR TEMP? Yes ☐ No ☒ TEMP. ____ °F. RISE ____ °F. FALL ____ °F.

WATER TEMP.: SUDDEN CHANGE: Yes ☐ No ☒ TEMP. ____ °F. RISE ____ °F. FALL ____ °F.

RECORDED APR 1 1969

SPEC. OF MAIN ______ CLASS OR THICKNESS 0.24 LAYING LENGTH 18 FT.

DATE LAID 1957 OPERATING PRESSURE 90 PSI. PREVIOUS BREAK REPORTED ______

INITIAL INSTALLATION DATA:

TRENCH PREPARATION: Native Material Blue Clay & Rock. (describe type) ☐ Sand Bedding ☐ Gravel Bedding ☐

BACKFILL: Native Material ☑ DESCRIBE Blue Clay & Rock. Bank Run Sand & Gravel ☐

Gravel ☐ Sand ☐ Crushed Rock ☐ OTHER ______

SETTLEMENT: Natural ☑ Water ☐ Compactors ☐ Vibrators ☐ OTHER ______ (describe)

### ADDITIONAL DATA FOR LOCAL UTILITY USE

LOCATION OF BREAK Argus Dr. Opposite Car Wash. MAP NO. 12

REPORTED BY Traffic Dept. — OAKVILLE P.U.C.

DAMAGE TO PAVING AND/OR PRIVATE PROPERTY 4'x8' Excavation on Road.

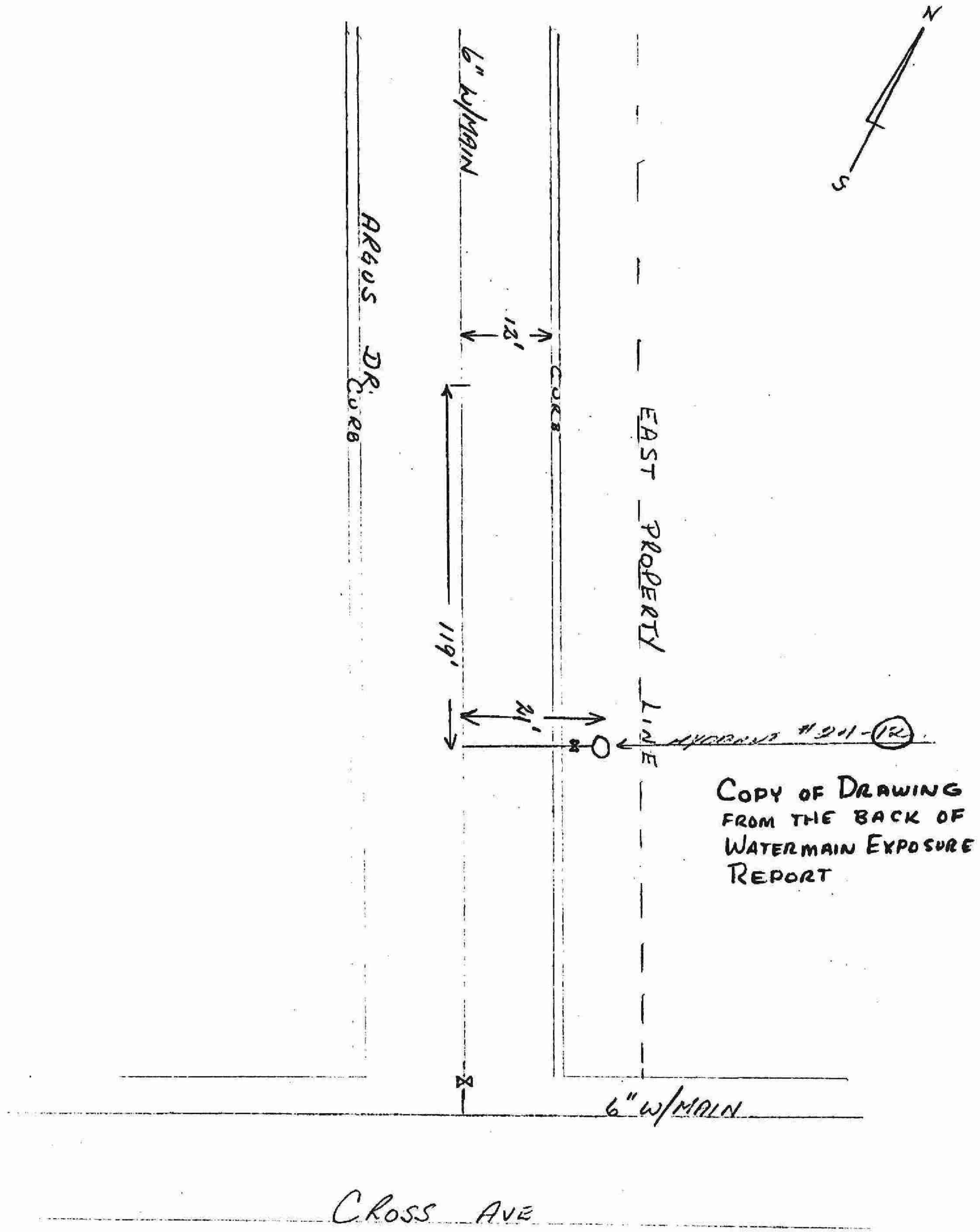
REPAIRS MADE (Materials, Labor, Equipment) 1-6"x6" Repair Clamp 1 Truck, Tractor 2 Plates 3 Men

REPAIR DIFFICULTIES (If Any) Main Laying on Rock, Trouble Getting Crew

INSTALLING CONTRACTOR OAKVILLE P.U.C.

Drawing on Back Yes. Foreman Sign. [signature]

Report Made By D. Bank Eng. Dept. Sign. P. J. [signature]


N
S
6" W/MAIN
ARGUS DR.
CURB
CURB
12'
119'
21'
EAST PROPERTY LINE
#211-12
COPY OF DRAWING FROM THE BACK OF WATERMAIN EXPOSURE REPORT
6" W/MAIN
CROSS AVE

L - 22

W.O. NO. W1194

# OAKVILLE PUBLIC UTILITIES COMMISSION
## FIELD NOTES

WATER SERVICE
HYDRANT
VALVES ON MAINS

DATE APRIL 24/69 STREET TRAFALGAR Rd LOT 3 NO. ?

OWNER OPUC

DATE LAID APRIL 24/69

LENGTH ____ MAIN TO CURB STOP 18 FT CURB STOP TO BASEMENT 42 FT

MIN. DEPTH AT MAIN 4½ FT +- CURB BOX 5 FT +-

MATERIAL 3/4 COPPER CORP. STOP 3/4" MAIN STOP 3/4"

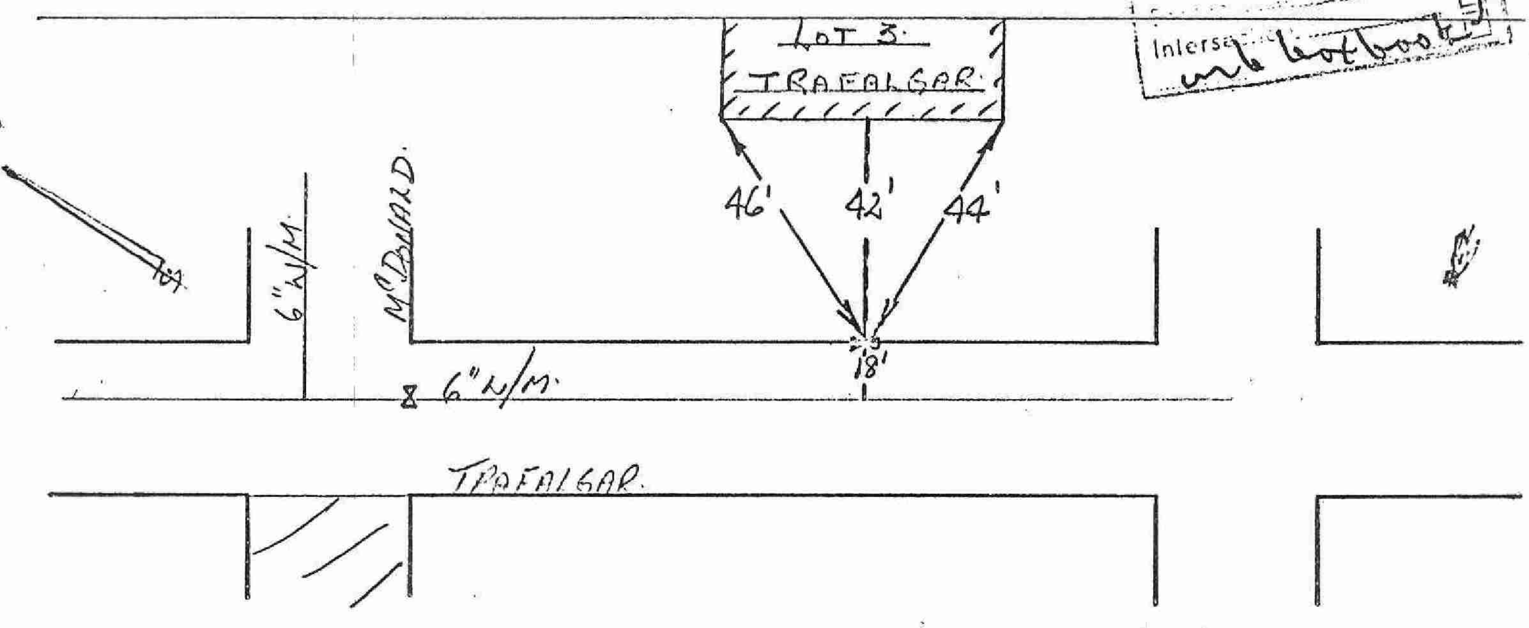
PIPE ____ POST ____

METER INSTALLED ____ SERIAL No. ____

REMARKS: CURB BOX TIES ARE TAKEN FROM THE WEST FACE OF THE HOUSE & THEY ARE

LEFT - 46 FT
RIGHT - 44 FT






DATE COMPLETED 4/24/69 DB CONNECTED 4/24/69

**THE OAKVILLE PUBLIC UTILITIES COMMISSION**
2350 TRAFALGAR ROAD
OAKVILLE 845-3461

№ 1101

**Combined Location and Confirmation Form for Underground Plant**

**REQUEST FOR LOCATION**

DATE ______

TIME ______

RECEIVED BY ______

**SITE OF LOCATION**

STREET ______

REQUESTED BY CONTRACTOR'S REP ______

CONTRACTOR ______

ADDRESS ______

**LOCATION DESIRED**

DATE ______

TIME ______

APPOINTMENT WITH ______

**ACTUAL LOCATION GIVEN**

SITE ______

DATE ______

TIME ______

SHOWN TO (CONTRACTOR'S REP.) ______

**UNDERGROUND PLANT**

TYPE LOCATED ______

METHOD OF MARKING STAKES ______ PAINT ______ TAPE ______

IT IS UNDERSTOOD AND AGREED THAT THE LOCATION AND MARKING OF ITS PLANT BY THE UNDERSIGNED PUBLIC UTILITY FOR THE UNDERSIGNED APPLICANT IS FOR THE CONVENIENCE OF THE SAID APPLICANT ONLY AND DOES NOT RELIEVE THE SAID APPLICANT, OR ANY OTHER PERSON OR CORPORATION, FROM LIABILITY FOR DAMAGES FOR PERSONAL INJURY INCLUDING DEATH TO ANY PERSON, OR FOR PROPERTY DAMAGE CAUSED TO THE SAID PLANT, OR TO ANY OTHER PROPERTY, BY REASON OF THE SAID APPLICANT, OR ANY OTHER PERSON OR CORPORATION HAVING RELIED UPON THE LOCATION AND MARKING OF ITS PLANT BY THE SAID PUBLIC UTILITY.

**LOCATION GIVEN BY** **LOCATION ACKNOWLEDGED BY**

UTILITY REP ______ CONT. REP. ______

WE APPRECIATE YOUR CO-OPERATION IN ASSISTING THIS UTILITY IN THE PROTECTION OF ITS UNDERGROUND PLANT. THANK YOU.

**DISTRIBUTION** WHITE – CONTRACTOR
PINK – OFFICE

2M-8/67-TLC

# BASIC HYDRAULICS

F. C. Ford, P. Eng.

Engineer, Design Approvals Branch
Division of Sanitary Engineering.

## INTRODUCTION

Hydraulics is the science of fluid flow. The science deals with the flow of fluids in pipes, channels, pumps, turbines, and other machines. However, in this paper we will be considering only the fluid of water and in a pipe or distribution system.

In this paper, we will consider some basic hydraulic principles, briefly discuss some common applications of these principles, and some measurements associated with the application of these principles. These notes will be useful in the operator's work in dealing with equipment and operation of a water system.

## UNITS

The use of correct units in hydraulics is essential. The formulas used in hydraulics are not complicated but demand that the correct units be used or otherwise incorrect solutions will result. If a particular unit is not in the form desired then we must be able to convert to the desired unit.

The definitions given below are required in the following part of the paper.

### Discharge

Discharge 'Q' is the volume of water passing a given point in a specific time. Operators are all familiar with the unit, gallons per minute (GPM), million gallons per day (MGD), and are perhaps less familiar with cubic feet per second (cfs). The operator must be able to convert from cfs to GPM to MGD with ease. To do this, the following rules apply:

| | | |
|---|---|---|
| 1 MGD | = | 694 GPM |
| 1 MGD | = | 1.86 cfs |
| 1 MGD (US) | = | 1.55 cfs |
| 1 cfs | = | 373 GPM |

## Pressure

Pressure 'P' may be expressed in terms of pounds per square inch (psi), pounds per square foot (psf), and feet of water (ft.). Inches of mercury can also be used but this is not common unless dealing with special gauges which do not concern the operator in this course. The following rules apply to pressure:

| | | |
|---|---|---|
| 1 psi | = | 144 psf |
| 1 psi | = | 2.31 ft. of water |
| 1 psf | = | 0.016 ft. of water |
| 1 ft. of water | = | 0.433 psi |

## Velocity

When referring to the speed of a car moving 30 mph, the reference is to the velocity of the car. Water velocity 'V' is expressed almost exclusively in feet per second (fps).

## Weight-Volume Relationships

The following conversions apply:

1 cubic ft. of water weighs 62.4 lbs.

1 gallon weighs 10 lbs.

1 US gallon weighs 8.33 lbs.

## Volume - Volume Relationships

The following conversions apply:

| | | |
|---|---|---|
| 1 Imperial gallon | = | 1.2 US gallons |
| 1 cubic ft. of water | = | 6.24 gallons |

PRINCIPLE OF CONTINUITY

This axiom is the most fundamental principle in hydraulics. Referring to Figure 1 at the back of the notes, the discharge 'Q' is the same in Section 1 as in Section 2 of the pipe. The velocity at Section 1 is $V_1$ and the cross-sectional area is $A_1$. The velocity at Section 2 is $V_2$ and the area is $A_2$.

A is expressed in square feet
V is expressed in fps
Q is expressed in cfs

We may, therefore, write the equation -

$$Q = A_1 V_1 = A_2 V_2 \qquad \text{Equation 1}$$

From Equation 1 and using simple mathematics, the following expressions may be determined:

$$V_1 = \frac{Q}{A_1} = \frac{A_2 V_2}{A_1}$$

$$V_2 = \frac{Q}{A_2} = \frac{A_1 V_1}{A_2}$$

Example

Given: $A_1 = 1.396 \text{ ft.}^2$ (16"Ø pipe)

$A_2 = 3.142 \text{ ft.}^2$ (24"Ø pipe)

Required: Find the velocity at Section 1 and Section 2 if the discharge 'Q' is 2340 GPM

Solution: $Q = 2340 \text{ GPM} = \frac{2340}{373} = 6.28$ cu. ft. per sec.

$$V_1 = \frac{Q}{A_1} = \frac{6.28}{1.396} = 4.5 \text{ fps}$$

$$V_2 = \frac{Q}{A_2} = \frac{6.28}{3.14} = 2 \text{ fps}$$

BERNOULLI PRINCIPLE

This theory is presented only to show the operator how various forms of energy exist in a water system. The operator is not expected to perform complicated calculations using the following formulas.

Bernoulli's principle deals with energy and says that the total energy in a system is always the same. However, the energy is in different forms at different locations in the system.

The energy may be in the form of:

1. pressure energy;
2. potential energy;
3. kinetic energy;
4. heat energy.

Energy is expressed in ft./lbs./lb. The lb. term cancels out and we refer to energy in terms of feet of water or feet of head.

Pressure Energy

Pressure energy or pressure head has been defined earlier in terms of psi, psf, and feet of water. When referring to pressure energy we will use the unit of feet of water. The line connecting the top of the pressure energies is called the hydraulic gradient. This is the line to which the water would rise if free piezometers were placed on the pipe line.

Kinetic Energy

The kinetic energy is the energy due to velocity and is defined as $\frac{V^2}{2g}$ where g is "acceleration due to gravity".

$$g = 32.16 \text{ ft./sec./sec.}$$

The kinetic energy is also in unit of ft.

Potential Energy

Potential energy is the energy of water due to its elevation (height) above a datum plane or reference point.

The unit again is feet since we are measuring only vertical distance.

## Heat Energy

Heat energy or head loss is created by the friction due to the water particles rubbing on each other and on the pipe walls and obstructions in the flow path.

This energy is lost from the system and can never be regained since the heat is dissipated through the pipe walls. Thus we call it head loss because the only useful energy in a water system is either velocity head, pressure head or potential head. Heat energy is created but velocity head, pressure head or potential head are lost. Losses due to heat energy will be discussed later in this paper.

Now we are ready to tackle Bernoulli's principle which deals with energy.

Figure (2) shows a water system with a water tank and a pipe out of the tank.

We are interested in what Bernoulli says happens at Sections 1, 2, 3, and 4.

At Section 1, the water in the tank is fairly still (V is approximately equal to zero) and the water level is remaining at the same elevation.

We can express the total energy at Section 1 as follows:

$$\text{Total Energy} = Z_1 + P_1 + \frac{V_1^2}{2g} \qquad \text{Equation 2}$$

$Z_1$ = the elevation difference from the bottom of the tank to the reference datum.

$P_1$ = the height of water from the tank bottom to the top of the water.

$\frac{V_1^2}{2g}$ = zero since the velocity in the tank is zero

Now consider Section 2.

$$\text{Total Energy} = Z_2 + P_2 + \frac{V_2^2}{2g} + H_{L1-2} \qquad \text{Equation 3}$$

$Z_2$ = the elevation difference from the centre line of the pipe to the reference datum.

$P_2$ = the height of water from the centre line of the pipe to the top of the water in the tank minus the friction loss from Section 1 to 2 ($H_{L1-2}$) minus the velocity head at Section 2.

$$\frac{V_2^2}{2g} = \left(\frac{Q}{A_2}\right)^2 \frac{1}{2g} \qquad \text{where } \frac{Q}{A_2} = V_2$$

Now consider Section 3.

$$\text{Total Energy} = Z_3 + P_3 + \frac{V_3^2}{2g} + H_{L1-3} \qquad \text{Equation 4}$$

$Z_3$ = elevation difference from centre line of pipe at Section 3 to the reference datum.

$P_3$ = the height of water from the centre line of the pipe at Section 3 to the top of the water in the tank minus friction loss from Section 1 to 3 ($H_{L1-3}$) minus the velocity head at Section 3.

$$\frac{V_3^2}{2g} = \left(\frac{Q}{A_3}\right)^2 \frac{1}{2g}$$

Now consider Section 4.

$$\text{Total Energy} = Z_4 + P_4 + \frac{V_4^2}{2g} + H_{L1-4} \qquad \text{Equation 5}$$

$Z_4$ = 0 since we have arbitrarily taken our datum through the centre line of the pipe

$P_4$ = 0 since the jet of water is discharging at atmospheric pressure

$$\frac{V_4^2}{2g} = \left(\frac{Q}{A_4}\right)^2 \frac{1}{2g}$$

Now applying Bernoulli's principle which says the total energies at all points are equal, we may write the following equation.

$$Z_1 + P_1 + \frac{V_1^2}{2g} = Z_2 + P_2 + \frac{V_2^2}{2g} + H_{L1-2}$$

$$= Z_3 + P_3 + \frac{V_3^2}{2g} + H_{L1-3}$$

$$= Z_4 + P_4 + \frac{V_4^2}{2g} + H_{L1-4}$$

Now consider the following example to calculate the discharge for the above situation.

Example

Given: Assume the water level in the tank at Section 1 is 50 ft. above the bottom of the tank and the bottom of the tank is 40 ft. above the discharge point at Section 4. $A_4 = 1.396$ ft.$^2$

Required: Find the discharge at Section 4

Assume $H_{L1-4} = 10$ ft.

Solution: Applying Bernoulli's theorem between Sections 1 and 4 we can say -

$$Z_1 + P_1 + \frac{V_1^2}{2g} = Z_4 + P_4 + \frac{V_4^2}{2g} + H_{L1-4} \qquad \text{Equation 6}$$

$Z_1 = 50$ ft.

$P_1 = 40$ ft. of water

$V_1 = 0$ Therefore $\frac{V_1^2}{2g} = 0$

$Z_4 = 0$ since our datum line is through the centre line of the pipe at Section 4.

$P_4 = 0$ since the discharge is to atmosphere

$\frac{V_4^2}{2g}$ is the unknown

$H_{L1-4} = 10$ ft. (given)

Therefore, inserting the values in the above Equation 6, we obtain the following:

$$50 + 40 + 0 = 0 + 0 + \frac{V_4^2}{2g} + 10 \text{ ft.}$$

Now we can solve the Equation since there is only one unknown.

$$\frac{V_4^2}{2g} = 50 + 40 - 10 = 80 \text{ ft.}$$

$$V_4^2 = 80 \times 2g$$

$$g = 32.16 \text{ ft./sec./sec.}$$

$$V_4^2 = 80 \times 2 \times 32.16$$

$$V_4^2 = 5140$$

$$V_4 = \sqrt{5140} = 71.8 \text{ fps}$$

$$Q = A_4V_4 \qquad A_4 = 1.396 \text{ ft.}^2$$

Therefore $Q = 71.8 \times 1.396 = 100$ cfs

## Head Losses

Head losses occur whenever the water flowing in a system encounters an obstruction. Remember that head loss is loss of heat energy. Head loss may be classified into the following categories:

1. major head losses
2. minor head losses

Head losses increase in direct proportion to the velocity head in the pipe. That is to say, the more water which is pushed through a given pipe, the more head loss which will result.

### Example

Given: The head loss in a 12-inch pipe is 5 ft. when the flow is 3.5 cfs (1.88 MGD).

Required: What is the head loss at 7.0 cfs

Solution: $V = \frac{Q}{A} = \frac{3.5}{.785} = 4.47$ fps

Therefore $\frac{V^2}{2g} = \frac{(4.47)^2}{2 \times 32.2} = .31$ ft. at Q = 3.5 cfs

When Q = 7.0 cfs

$$V = \frac{7.0}{.785} = 8.94 \text{ fps}$$

$$\frac{V^2}{2g} = \frac{(8.94)^2}{2 \times 32.2} = 1.23 \text{ ft.}$$

Thus the head loss at 7.0 cfs is -

$$\frac{1.23}{.31} \times 5 = 20 \text{ ft.}$$

This example illustrates that by doubling the flow the head loss is quadrupled.

<u>Major Losses</u>

The losses which we refer to as major losses occur in straight lengths of pipe. These losses are called major because in a real water distribution system most losses occur due to the long length of pipe through which the water must pass. As the operator knows, the farther the water must flow through a pipe, the less water can be gotten out without adding more energy. The obstructions which cause these type of losses in a pipe are the roughness projections of the pipe. The walls of a pipe have small projections protruding in the path of the water thus causing the water to flow around the obstructions. This causes heat to be generated and energy is lost from the water. When cast-iron pipe becomes old and gets rusty and encrusted, the discharge decreases through such a pipe. What is happening is the water is losing energy more quickly than in a new pipe.

The following classification can be used for outlining the obstructions encountered in pipe for water supply systems:

1. Tuberculation of unprotected steel linings;
2. Calcareous deposits;
3. Slime growths;
4. Organic growths.

Tuberculation: This can be described as the incrustations formed by the erosion of iron pipes, valves, and other iron works which are not protected. These incrustations can reach a thickness of 1 - 1-1/2 inches. Theoretically we can ream out the pipe taking off these protrusions and thus obtain less head loss in the pipe. However, this also reduces the life of the pipe as a result of the more rapid corrosion of the remaining iron.

Calcareous Deposits: These are translucent and semi-crystallized scale of calcium carbonate formed by the escape of carbonic acid from water containing bicarbonate of lime. These deposits would be expected in hard water.

Slime Deposits: These are not usually encountered in well supplies but are more common in unfiltered surface water supplies.

Organic Growths: These growths are the type usually associated with iron bacteria. These growths may attain a thickness of up to 1/4 to 1/2 inch. The material is usually slimy and fibrous. These growths may be prevented by proper chlorination. If such growths are causing trouble in the distribution system, then flushing the system out through the hydrants is usually beneficial.

## Minor Losses

These losses occur in localized areas of the water system and are usually associated with the water changing direction due to an obstruction.

Minor losses occur in the following places:

1. valves;
2. elbows and bends;
3. Wyes;
4. Tees;
5. sudden contractions and reducers;
6. sudden enlargements and increasers;
7. flow meters;
8. tank entrances;
9. tank outlets;
10. screens.

Let us examine the loss through a gate valve in some detail. As would be expected, the loss through a gate valve which is wide open is less than a throttled gate. This is due to decreased area through which the flow must pass in a throttled gate. If the area is less, the velocity must increase, thus increasing the head loss.

Tables are available for calculating major and minor losses. These tables will not be required in this course.

## Hydrant Tests

The operator may be involved in performing flow tests on the distribution system to determine the flows available for either fire fighting purposes or normal demand. By performing flow tests, weak points in the distribution system, which cannot supply the desired quantity of water, can be located. The test consists of determining the pressure drop at a fire hydrant for a measured flow from a nearby hydrant or hydrants and using a ratio to determine the head loss for other flows.

### Equipment Required (Figures 3, 4, and 5)

The equipment required includes a cap to cover the 2.5 inch outlet of the hydrant at which the pressure is to be read. Into the cap is tapped a 1/4 inch copper pipe which has a T-connection for a 100 psi pressure gauge. At the end of the pipe is a cock to allow air to escape. There is also a stop cock on the line to the gauge. This equipment is shown in Figure 3.

A Pitot tube with air chamber and pressure gauge is necessary for checking the velocity pressure of the water at the nozzle. A Pitot tube may be several suitable types. The type shown in Figures 4 and 5 may be readily constructed. It should be connected by brass or other non-ferrous metal pipe fittings to an air chamber and pressure gauge as shown. The Pitot tube should be kept free of dirt and the air chamber free of water. The gauge should read to 50 psi in 1/2 graduations. The assembly is obtainable from manufacturers of Pitot equipment.

### Method

When a test is made, one or more hydrants are chosen for measuring discharge and one is chosen for reading residual pressure. If several hydrants are opened for flow, they are grouped about the one observed for

pressure as for hydrant R in Figure 6. If a dead end line is being tested, the end hydrant should be the residual hydrant and the next nearest would be the opened one.

The test is begun by opening the air escape cock of the pressure gauge at the residual hydrant and then opening the hydrant valve. After the air has escaped, the cock is closed and the pressure is read. If the needle fluctuates, the centre point is read.

Then at a signal, one hydrant is opened and both the residual and Pitot pressures are read. At a signal, the next hydrant is opened and readings are made, and so on, until all hydrants to be opened are flowing. Then the hydrants are closed, slowly to prevent waterhammer, and the final pressure at the residual hydrant should return to the pressure before the test was started.

If the tests are to be significant, the following precautions should be observed:

1. The hydrants tested should form a group such as might be called into play in fighting a fire in the area under study.

2. Water should be drawn at a sufficient rate to create a drop in pressure greater than that caused by normal fluctuations in draft within the system. There should be sufficient flow to insure a pressure drop of at least 10 psi and also not so much that the residual will be reduced to 20 psi.

3. The time of the test should coincide with normal draft periods in the remainder of the system.

The hydrant discharge rate $Q_H$ (gpm) can be found directly in Table 1.

The Canadian Underwriters' Association generally prescribes that there should be a residual pressure of 20 psi. It is necessary to adjust the actual readings to determine flow which would occur with a residual of 20 psi in a nearby hydrant. This is done using the formula:

$$Q_A = Q_T \sqrt{\frac{h_A}{h_T}}$$

in which $Q_A$ is the flow available with a residual of 20 psi, $Q_T$ is the test flow, $h_A$ is the pressure drop available and $h_T$ is the pressure drop during the test.

<u>Example</u>:

For example, in Figure 6, if the hydrant nozzles are 2.5 inches inside diameter, the following table represents a typical test where the pressure has been observed with a pressure gauge at hydrant R before and after the test, and outlet pressures have been measured by the Pitot gauge at hydrants 1 to 4 inclusive.

| Conditions | Observed Pressure at HYD R (psi) | Observed Velocity Pressure (psi) | Calculated Flow From Formula (gpm) |
|---|---|---|---|
| All hydrants closed | 74 | -- | -- |
| Hydrant 1 open | -- | 13.2 | 510 |
| Hydrant 2 open | -- | 9.6 | 435 |
| Hydrant 3 open | -- | 16.8 | 575 |
| Hydrant 4 open | -- | 14.5 | 535 |
| All hydrants open | 46 | -- | -- |
| All hydrants closed | 74 | -- | -- |
| | | Total | 2055 |

The simultaneous flow readings of all four hydrants produced a total flow of 2055 gpm. At this flow, the residual pressure at Hydrant R dropped 74-46 = 28 psi. The adjusted flow with a residual of 20 psi is therefore:

$$Q_A = 2055 \sqrt{\frac{74-20}{74-46}} = 2850 \text{ gpm}$$

## LIST OF SYMBOLS & ABBREVIATIONS

| | | |
|---|---|---|
| Q | - | discharge in cfs, MGD or GPM |
| P | - | pressure in psf, psi or ft. of water |
| V | - | velocity in fps |
| A | - | cross-sectional area in ft.$^2$ |
| g | - | acceleration due to gravity = 32.16 ft./sec./sec. |
| $H_L$ | - | head loss in ft. |
| Z | - | potential energy in ft. |
| $\frac{V^2}{2g}$ | - | velocity head or kinetic energy in ft. |
| WL | - | water level |
| cfs | - | cubic feet per second |
| MGD | - | million gallons per day |
| GPM | - | gallons per minute |
| psf | - | pounds per square foot |
| psi | - | pounds per square inch |
| ft. | - | feet |
| ft.$^2$ | - | square feet |
| fps | - | feet per second |
| sec. | - | second |

# TABLE 1

## DISCHARGE TABLE FOR CIRCULAR OUTLETS

Outlet Pressure Measured by Pitot Gague

| Outlet Pressure psi | Outlet Diameter 2½ in. | Outlet Pressure psi | Outlet Diameter 2½ in. |
|---|---|---|---|
| 1 | 140 | 32 | 792 |
| 2 | 198 | 33 | 804 |
| 3 | 242 | 34 | 816 |
| 4 | 280 | 35 | 828 |
| 5 | 313 | 36 | 840 |
| 6 | 343 | 37 | 852 |
| 7 | 370 | 38 | 863 |
| 8 | 396 | 39 | 874 |
| 9 | 420 | 40 | 886 |
| 10 | 442 | 41 | 896 |
| 11 | 464 | 42 | 907 |
| 12 | 485 | 43 | 918 |
| 13 | 505 | 44 | 929 |
| 14 | 524 | 45 | 939 |
| 15 | 542 | 46 | 949 |
| 16 | 560 | 47 | 960 |
| 17 | 577 | 48 | 970 |
| 18 | 594 | 49 | 980 |
| 19 | 610 | 50 | 990 |
| 20 | 626 | 52 | 1009 |
| 21 | 642 | 54 | 1029 |
| 22 | 657 | 56 | 1047 |
| 23 | 671 | 58 | 1066 |
| 24 | 686 | 60 | 1084 |
| 25 | 700 | 62 | 1102 |
| 26 | 714 | 64 | 1120 |
| 27 | 727 | 66 | 1137 |
| 28 | 741 | 68 | 1154 |
| 29 | 754 | 70 | 1171 |
| 30 | 767 | 72 | 1188 |
| 31 | 779 | 74 | 1204 |

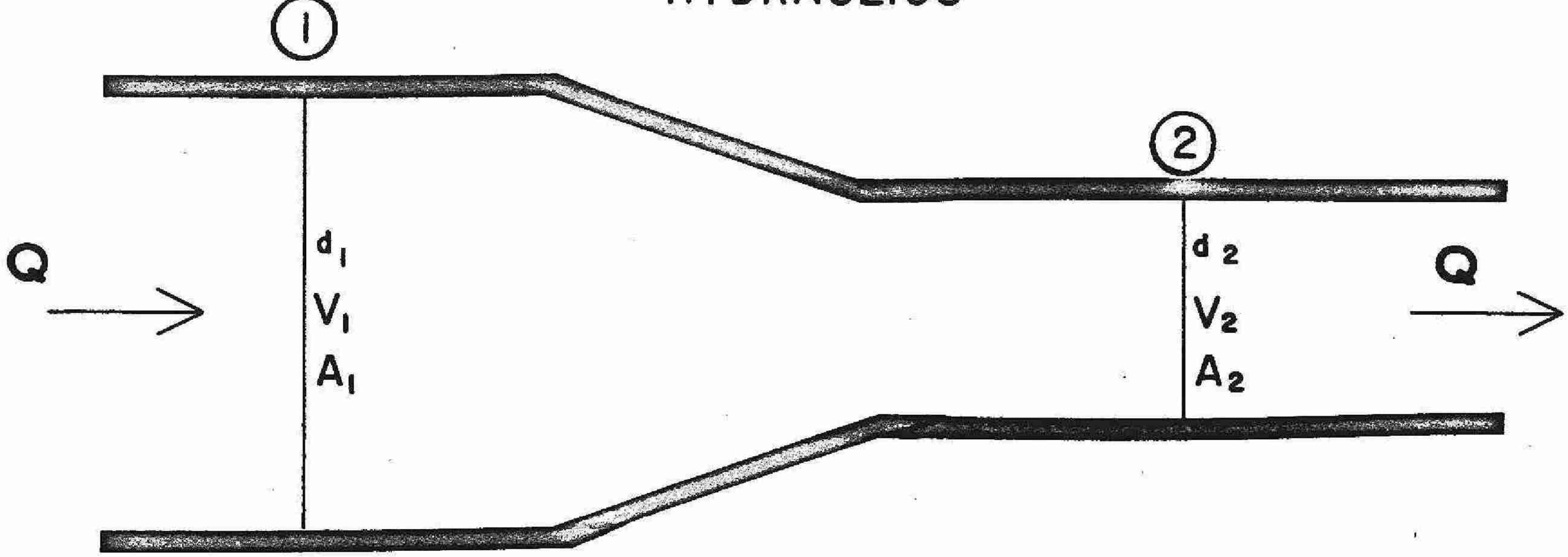
Orifice co-efficient C = 0.9

FIGURE 1

# CONTINUITY PRINCIPLE

INTERMEDIATE WATER WORKS OPERATORS COURSE

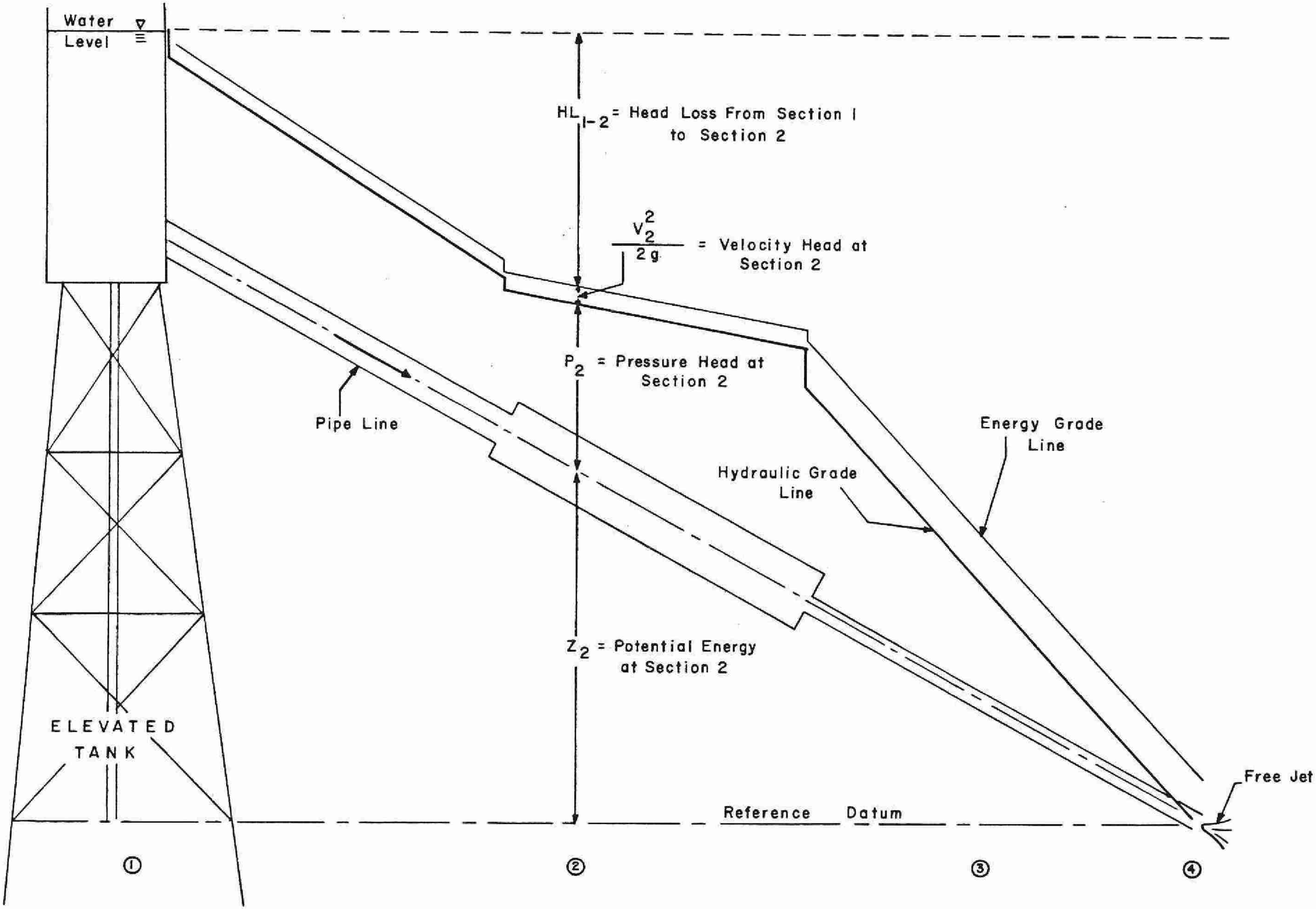
HYDRAULICS




$$Q = A_1 V_1 = A_2 V_2$$

$$V_2 = \frac{A_1 V_1}{A_2}$$

FIG.-2
BERNOULLI PRINCIPLE

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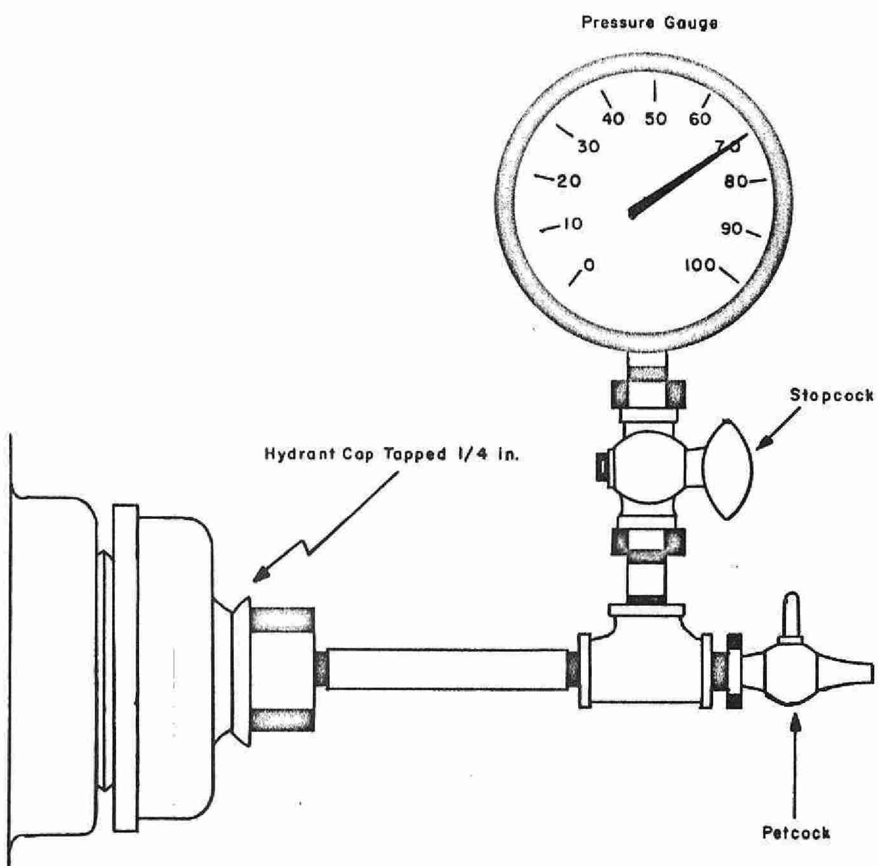
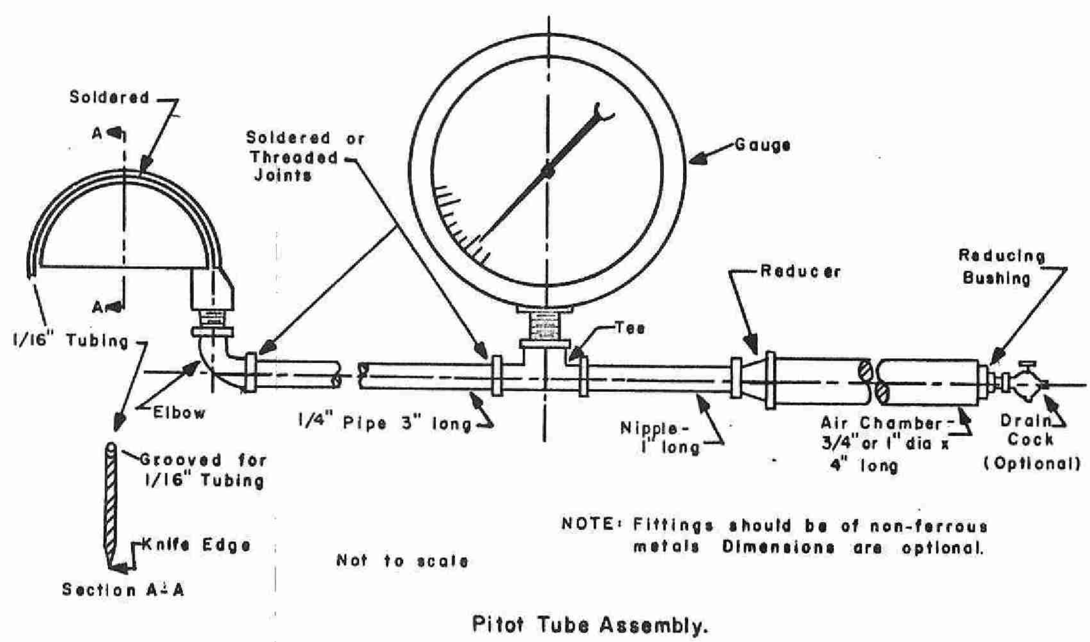
# HYDRAULICS




Gauge Assembly for Measuring Hydrant Pressures

FIG.—3




Pitot Tube Assembly.

FIG.—4

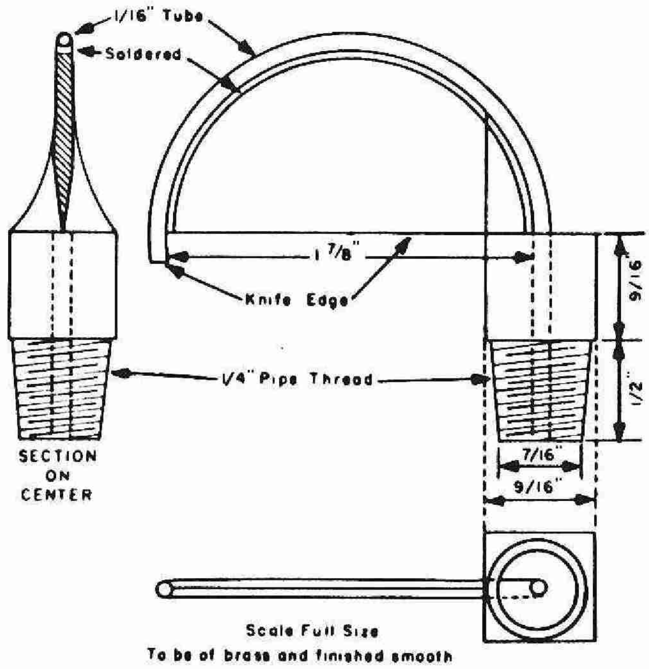



**FIG. 5** Nozzle Stream Pitot.

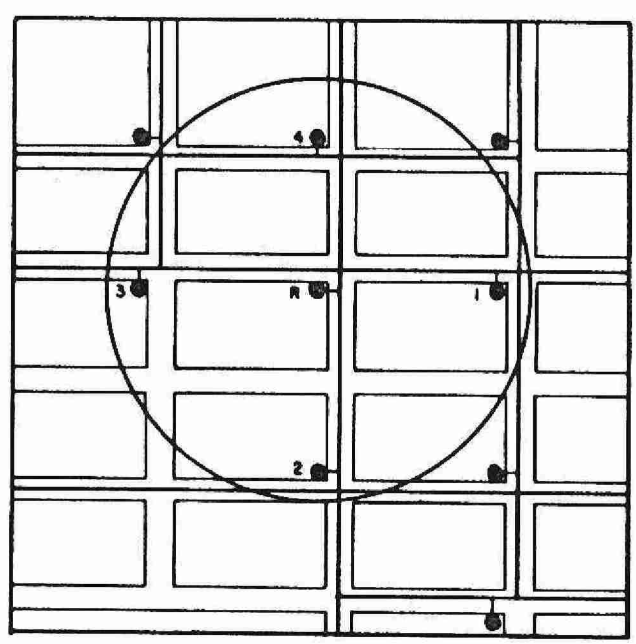



FIG. 6

# PART II

# OPERATION AND MAINTENANCE

# OF

# DEEP WELLS

# GROUND WATER EXPLORATION AND DEVELOPMENT

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## INTRODUCTION

Water can be considered as one of the most important natural resources of this province. In this discussion, we will deal with that water which occurs in the saturated portions of the overburden and the rock. This water is called ground water. It is estimated that at the present time, over 30 percent of the total water used in Ontario is ground water. In the planning of any community, water plays a major part. Little progress can be made if water supplies are either inadequate or of unsatisfactory quality. As the community expands the water requirements in all phases of personal, communal, and industrial life becomes increasingly important. In Ontario alone, 35 percent of the population is dependent upon ground-water sources of supply. Ground-water development is therefore of continuing importance to a large section of the population.

Table 1 - Ground Water and Municipal Water Supplies

| | Total Number | With Water Supply Systems | Those Using Ground Water | Percentage Using Ground Water |
|---|---|---|---|---|
| Cities | 33 | 33 | 8 (not London) | 24 |
| Towns | 152 | 139 | 53 | 28 |
| Villages | 155 | 77 | 37 | 48 |
| Townships | 562 | 77 | 28+ | 37 |
| Improvement Districts | 18 | 6 | 3 | 50 |

\+ indicates that in some townships more than one system using ground water exists.

Before an attempt is made to discuss ground-water development, it is essential to understand the natural environment and natural forces that are responsible for the occurrence, storage, and movement of ground water.

## GROUND WATER OCCURRENCE AND MOVEMENT

### Ground Water Zones

The formations of the earth are divided into three major zones with regard to water supply (see Figure 1):

1. Zone of Aeration
2. Zone of Saturation
3. Zone of Rock Flowage

The Zone of Aeration can be defined as the zone in which the open spaces in permeable formations are not filled regularly with water. This zone does not contain water in usable quantities for water supply but acts rather as a medium through which moisture can travel downward to replenish the Zone of Saturation.

The Zone of Saturation occurs directly below the Zone of Aeration and is defined as the zone in which the functional permeable formations are saturated with water under pressure equal to or greater than atmospheric.

The Zone of Rock Flowage is defined as the deep part of the earth in which all rocks are under stresses exceeding their elastic limits. Water occurring in this zone is formed by chemical reactions within the rocks themselves and is of no value as a potential source of water supply.

### The Hydrologic Cycle

Ground water is one phase of the hydrologic cycle. The cycle consists basically of precipitation, runoff (both on the surface and underground), transpiration, evaporation, and precipitation again. Ground water is an aspect of runoff which has resulted from the absorption of moisture at the earth's surface, downward movement of the moisture through the Zone of Aeration to the Zone of Saturation, and then lateral movement under the influence of gravity to a point of natural or artificial discharge. As an example, moisture-laden air

moving over the land masses from the oceans drops about 30 inches of precipitation in the form of rain and snow on North America every year. Of this amount, 60 to 80 percent is returned to the atmosphere by direct evaporation as it falls, by evaporation from the land surface, by evaporation from bodies of surface water, by evaporation from vegetation, and by transpiration from the plants which draw water up from the soil through their roots. Of the remaining portion, 10 to 20 percent reaches surface-water bodies directly as surface runoff. Some of the remainder infiltrates into the ground to form the soil moisture which is available to vegetation and a very small amount, probably about 10 to 20 percent, moves downward to become ground water in the saturated zone, (see Figure 2).

Water in the saturated zone moves under the influence of gravity at rates of from about five feet per day to about five feet per year, until it reappears at surface as a spring or discharge into a stream, lake, or ocean.

## Geological Controls as Related to Ground Water

Geology affects the framework in which ground water occurs. It includes the stratigraphy and structure of the overburden and rock formations which together house the intricate ground-water system.

Geological factors relate chiefly to the formations and their water-bearing properties and hydrologic factors relate to the movement of water in the formations. The permeability, or capacity of transmitting a fluid, of the formations is the result of the geological agencies. These agencies are responsible for the forming and altering of the overburden and rock strata thus developing their water-bearing properties.

The interstices in rocks and overburden deposits are the open spaces in which the water can occur and move. They differ widely in size, shape, arrangement, and aggregate volume. The openings through which water moves range in size from huge limestone caverns and lava tubes through all gradations to the minute pores in clay. Even smaller openings of molecular dimentions are of significance in relation to absorption phenomena. The interstices are generally irregular in shape, but different types of irregularities are characteristic of deposits of different kinds, (see Figure 3).

Interstices of the rocks and overburden materials can be grouped into two major classes. Original, or primary interstices that date back to the formation of the rock or overburden deposits and secondary interstices, such as joints, fissures, and solution passages which have developed later. Generally the original interstices have been altered by solution, cementation, recrystallization, or other processes.

Water in unconsolidated materials moves through the interstices. Clean, coarse gravel is the most productive unconsolidated water-bearing material. Progressively poorer water-bearing materials range downward from clean, coarse sand to very fine sand and silt and heterogenous mixtures of fine and coarse particles such as are found in glacial till.

The consolidated rocks which were formed by solidification of molten rock and those developed from unconsolidated sedimentary deposits through pressure, cementation, and crystallization are commonly jointed and contain a large proportion of their water in these joint cracks. Less thoroughly cemented sandstones yield most of their water from pores and are amongst the most productive of the consolidated rocks. Other highly productive rocks include limestones and dolomites which contain water along joints, fractures, and in solution cavities.

Rocks and unconsolidated sediments that do not yield water freely but which furnish water where better aquifers or water-bearing formations are lacking, include fine grained and poorly sorted overburden deposits and jointed crystalline rocks such as granite.

The capacity of any rock or overburden material to absorb, hold or yield water is dependent on its porosity which is the ratio of the aggregate volume of the interstices in a rock or soil to its total volume (this value is usually referred to as a percentage). In consolidated rocks the original porosity usually has been reduced by compaction or by deposition of cement in the pore spaces, although the total porosity may have been increased by development of fractures or by dissolving of some of the rock material.

Rocks of low porosity necessarily are limited in their capacity to absorb, hold or yield water but it is not necessarily true that rocks of high porosity are capable of yielding large quantities of water. One saturated rock may yield most of the water contained in its pores to wells or springs, whereas another having equal porosity but smaller pores, may retain practically all of its water and yield negligible quantities to wells. Where the porosity is identical, the difference is in the proportion of the contained water that is held by molecular attration and the proportion that can be moved by gravity or hydrostatic pressure. Molecular attraction becomes increasingly significant with decreasing size of the interstices, because of the increased surface area of solid material to which water can adhere.

A general range in porosity of natural sediments and sedimentary rocks is given in Table 2.

Table 2

| Materials | Porosity Percent |
|---|---|
| Sandstone | 4-30 |
| Sand, clean and uniform | 30-40+ |
| Gravel, clean and uniform | 30-40+ |
| Sand and gravel mixed | 15-25 |
| Silt and clay | |
| As deposited | 40-90 |
| Compacted and dewatered | 20-40 |
| Shale | 1-35 |
| Limestone | 1-50 |

In the development of ground water by means of wells, a hole is drilled into the Zone of Saturation and water drains from the overburden material or rock into the well. As the water is pumped, the reduced hydrostatic pressure at the well

causes movement of water toward the well. The rate at which water can be withdrawn depends on the permeability of the material. Rock or overburden horizons that yield water in sufficient quantities to be of consequence as a source of supply are called aquifers or ground-water reservoirs. The ground-water reservoirs, like surface reservoirs, serve the same general purpose in that they tend to smooth out the daily and seasonal fluctuations in the amount of water supplied by precipitation. Ground-water reservoirs absorb water during periods of surplus and release it to springs or other avenues of discharge providing most of the stream flow during rainless periods.

Water Table and Artesian Aquifers

In areas where the materials are permeable down to the Zone of Saturation the aquifers are said to be under water-table conditions and the level of the water in the well and aquifers is called the water table. The water in this aquifer is unconfined.

Impermeable layers above the Zone of Saturation produce various complications to this simple picture. Such layers may be at the surface and practically all water from precipitation must collect on the surface or runoff over the land surface. Impermeable materials such as clay or glacial till may be present at various depths and retard downward percolation, so that there is an accumulation of water or temporary saturation immediately above the impermeable strata, this constitutes ground water that is perched above the main Zone of Saturation.

Many deep wells penetrate far into the Zone of Saturation and go through materials that range widely in permeability. As these wells are being drilled, water may rise markedly above the top of the aquifer that is being tapped and may even overflow at the surface. Such water is confined beneath less permeable material and is said to be under artesian conditions, (see Figure 4).

An artesian aquifer does not receive significant quantities of water by downward movement through the confining beds that overly it. Even in places where the confining bed is moderately permeable the artesian pressure opposes some of the downward movement. An artesian aquifer is replenished mainly in some area where the confining bed does not exist and where ground water is under water-table conditions. The area that supplies water to the artesian aquifer is known as a recharge area.

The amount of storage in an aquifer is no indication of the aquifer's capabilities for sustained yield of water to wells or springs. The limit of perennial yield is set by the average annual recharge to the reservoir just as the useful yield of a surface reservoir is set by the inflow to it. Capability of the aquifer for sustained yield is determined by the quantity of inflow to that reservoir in its recharge area. This infiltration in recharge areas is of critical importance and the identification and delineation of recharge areas is as important as defining the position and extent of aquifers in an area.

## WATER-BEARING PROPERTIES OF ROCK FORMATIONS

The Precambrian granites and other intrusive, sedimentary, and volcanic rocks underlie 60 percent of the area of the province, chiefly in northern Ontario. As a rule, these formations are classified as poor aquifers. Wells may obtain sufficient water for average domestic needs from joints, cracks, or fracture planes near the surface of these rocks but high-capacity wells are confined almost entirely to the sand and gravel deposits in the overburden above them.

The limestones and dolomites of southern Ontario vary widely in their water-yielding properties. They often make better aquifers in the southwestern parts of the province than they do in south-central or eastern Ontario. The quality of the water is generally very hard and is often highly mineralized with sulphur compounds, particularly in the areas closest to lakes Erie and Ontario and the St. Lawrence River.

The shale formations yield only small quantities of water but the water is much softer than that from the limestone rocks. Salty water is frequently encountered at shallow penetrations of the shale formations.

A wide variety of overburden conditions is present in Ontario. Although much of the area is covered on the surface of the ground with clay or till materials, numerous deposits of sand and gravel are present to provide in most places suitable aquifers for average domestic needs. Areas where there are high-capacity wells for municipal, industrial, or irrigational purposes are necessarily more restricted.

Principal Occurrence of Overburden Aquifers

Unconsolidated deposits of sand and gravel generally form the aquifers that supply large quantities of ground water from the overburden. Other overburden deposits are also used as sources of ground water but usually these are capable of yielding little more than domestic supplies.

The types of occurrence of overburden aquifers may be grouped broadly as follows:

1. Glacial deposits
2. Buried valleys
3. Watercourses.

1. Glacial Deposits

Important ground-water reservoirs occur in permeable deposits left by melting ice associated with retreating glaciers. Eskers, kames, outwash plains, deltas, and sand dunes are all potential sources of ground water.

2. Buried Valleys

Buried valleys are no longer occupied by the streams that formed them. Drainage systems were disrupted by advancing and retreating ice during geological times. Permeable sediments left in channels were buried by younger sediments and often constitute favourable aquifers.

3. Watercourses

Watercourses are hydrologic units that involve both surface water and ground water. The wells tapping these aquifers frequently are so placed that water pumped from them is readily replaced by infiltration from rivers or streams. The water yield is generally large.

Principal Types of Bedrock Aquifers

In order to understand the water-bearing properties of the various rock types it is necessary to define the three classes into which all rocks are divided:

1. Sedimentary rocks are rocks formed by the accumulation of sediments in water or on land.

2. Igneous rocks are rocks formed by solidification from a molten or partially molten state.

3. Metamorphic rocks are rocks formed in response to pronounced changes of temperature, pressure, and chemical environment.

## 1. Sedimentary Rocks

In general sedimentary rocks are better aquifers than are either igneous or metamorphic rocks. The importance of sedimentary rocks as aquifers depends greatly upon the degree of sorting of the grains, the amount of cementation and the type of cementing material. In order of importance they can be classified as follows: sandstone, conglomerate, dolomite, limestone, and shale. Water occurs within the interstices, joints and fractures.

## 2. Igneous Rocks

As a rule, igneous rocks are not good water producers. Some fine grained volcanic rocks are good aquifers due to permeable zones located in large joint openings and in zones of fragmentation that often occur between lava sheets. In the coarse grained igneous rocks water is confined to joints, cracks, and along fault zones. These openings tend to become tighter and fewer in number with increasing depth.

## 3. Metamorphic Rocks

As in the case of igneous rocks, metamorphic rocks are generally poor aquifers, the water occurring mainly in joints, fractures, and along fault and cleavage planes.

If the bedrock remained undisturbed from the time it was deposited or intruded, the study of ground water would be relatively simple. As it is, this is seldom the case as most rocks are subjected to varying amounts of stress which result in gentle warping or intense folding and fracturing. Deformation of this nature complicates matters. A water table may cut across a series of folded beds in such a manner that a particular geological horizon may in places lie above and in other places below the water table; movement along fracture planes may be such that an aquifer may abut against material that does not transmit water or a fracture plane may be filled with broken rock which could be important as a source of ground water.

An almost infinite number of situations may arise due to deformation which would necessitate a careful study of the rock structures before an appraisal could be made of the ground-water potential of the geological horizons under investigation.

## GROUND WATER EXPLORATION

Modern ground-water development is the practical application of technical knowledge to the provision of water supplies for beneficial use, free from pollution and in accordance with the best principles of ground water conservation. This requires not only a knowledge of well-drilling equipment and methods, but also a comprehensive understanding of geology, hydrology and ground-water chemistry.

The larger ground-water users such as municipalities and industries require detailed information on the feasibility of proposed developments before actually undertaking any drilling. This information can be obtained at a reasonable cost by a well planned, preliminary investigation programme.

### Prospecting and Testing

To establish definite and feasible ground-water developments, any drilling should be preceded by sufficient study and investigation. It is often necessary to resort to geological and geophysical methods in the field, using techniques that will obtain the required information quickly and with reasonable accuracy. From this preliminary work, it can be deduced where the best aquifers are located, what their extent and general nature is, and where test drilling is warranted.

#### 1. Geophysical Exploration

Geophysical methods of exploration consist of the measurement and identification of changes in certain physical properties of the earth at or near the surface. At present, the geophysical methods most applicable to ground-water prospecting are the seismic, electrical-resistivity and gravity methods. They involve, respectively, the measurement of the rate of propagation of elastic waves in the earth, changes in the electrical resistance of the earth and the measurement of

the total gravitational field of the earth. These three methods were primarily developed for use in prospecting for petroleum and minerals. Adapatations and modifications of these basic methods are extensively used for ground-water prospecting.

When used in conjunction with geological data, the methods, under favourable conditions, give results which indicate the character and sequence of strata and the depth to bedrock. The full value of these methods are obtained in their correlation with, and as supplements to, other data.

2. Geological and Hydrologic Surveys

During a survey of this nature the exposed overburden and bedrock geology is carefully examined and hydrologic and water-quality data are collected from existing wells, test wells, test holes and observation holes in the area under investigation. This information is compiled and plotted on a base map and used in conjunction with topographical details to construct geological sections and contour maps of the bedrock and water table or piezometric surface. (The piezometric surface is the level to which water from a given artesian aquifer will rise under full head). Details of the geology, the bedrock surface elevations and directions of natural ground-water flow, are used in association with pumping tests, water quality and geophysical data to determine the location and characteristics of the various aquifers in the area under investigation.

Test Drilling

If geological, geophysical and hydrology conditions indicate that a further investigation of ground-water conditions is warranted, a test-drilling programme should be instigated. To put down test holes, standard drilling equipment should be used, the type depending on the nature and depth of the formations to be penetrated. As the purpose of all test holes is to obtain accurate formation data and representative samples, it is essential that the character of the holes and drilling methods used be such that the results are accurate and dependable. A programme of testing must be carefully planned in advance. The following procedures should be undertaken.

1. A sufficient number of test holes should be drilled to determine the area, thickness, and depth of the best aquifer within the sector available for development.

2. Test holes should be at least 4 inches in diameter. Gauge holes can be 2 inches in diameter.

3. All formation samples should be as nearly representative of the natural formations as possible.

4. All formation samples to be examined should be placed in containers on which depth, location and other information are marked.

5. Samples of water from each aquifer penetrated should be taken during drilling.

6. All analyses of formation and water samples should be made by persons who are experienced in such work and are qualified to interpret the hydrologic, as well as the geological characteristics of the samples.

## GROUND WATER EXTRACTION AND DEVELOPMENT

### Well Design and Construction

Assuming that the preliminary investigation, prospecting and testing have been completed and the feasibility of developing a ground-water supply has been established, the next step is the construction of the necessary wells.

### Selection of Well Type

One of the fundamentals of ground-water development is to select the proper type of well for the aquifer and water use.

The Committee of the American Water Works Association has prepared a complete set of well specifications. The specifications are as follows:

1. The proposed well should be constructed of materials that give the longest life under the soil, water and pumping conditions which are already present in the ground formations or which may result from the operation of the well.

2. The proposed well should be constructed so that it will make the maximum quantity of water available for pumping with the least possible drawdown per gallon.

3. The proposed well should be so constructed that only usable water can enter it at any place and only through the openings provided for this purpose.

Wells Ending in Sand and Gravel Deposits

Many of the large capacity municipal wells in the province obtain water from sand and gravel deposits. The main problem involved in the construction of a well in sand and gravel is to prevent the entry of fine grained particles of silt and sand into the well. This is accomplished by using a well screen to hold our the coarser materials and developing the well thoroughly during the construction to remove the fine particles from the sand and gravel formations near the well. Well screens should be selected according to the character of the water-bearing formation and the size of the materials introduced in any gravel pack. Current design practice uses a screen that permits 40 to 70 percent of the sands and gravels around the well to be drawn through the screen and removed. The yield of a well can normally be increased much more through increasing the length of the screen than through increasing the diameter of the screen.

Many kinds of metals are used in well screens. The alloys generally have a greater tensile strength and resistance to corrosion than the unalloyed metals. Table 3 lists many of the metals used in well screens together with a summary of the tensile strength and the resistance to corrosion by water and acid treatment.

Table 3

Properties of Metals Used in Well Screens

| Name of Metal | Analysis | | Tensile Strength psi | | Resistance to | |
|---|---|---|---|---|---|---|
| | | | Yield | Ultimate | Corrosion by Water | Acid Treatment |
| Everdur | Copper | 96% | 90,000 | 115,000 | Very Good | Very Good |
| | Silicon | 3% | | | | |
| | Manganese | 1% | | | | |
| Stainless Steel | Steel | 74% | 90,000 | 110,000 | Very Good | Good |
| | Chronium | 18% | | | | |
| | Nickel | 8% | | | | |
| Monel | Nickel | 70% | 75,000 | 100,000 | Excel-lent | Very Good |
| | Copper | 30% | | | | |

Table 2 (Cont/d)

| Name of Metal | Analysis | | Tensile Strength psi Yield | Ultimate | Resistance to Corrosion by Water | Acid Treatment |
|---|---|---|---|---|---|---|
| Solicon Red Brass | Copper<br>Zinc<br>Silicon | 83%<br>16%<br>1% | 72,000 | 83,000 | Good | Good |
| Super Nickel | Copper<br>Nickel | 70%<br>30% | 67,000 | 69,000 | Excel-lent | Very Good |
| Armco Iron | Iron | 99.84% | 50,000 | 55,000 | Fair | Poor |
| Steel | Manga-nese<br>Carbon | .20/.50%<br>.08/.15% | 45,000 | 50,000 | Poor | Poor |

The two main types of wells used for sand and gravel formations are natural sand and gravel wells and gravel-packed wells. Other names for gravel-packed wells are gravel-filter or gravel-wall wells.

Natural Sand and Gravel Wells

The main components of natural sand and gravel wells are a protective casing which extends from above the surface of the ground to or into the water-bearing formation and a well screen which is set opposite the water-bearing formation. If the water-bearing formation is thick and contains layers of fine-grained sediments, sections of well screen may be set opposite the coarser materials and blank sections of pipe set opposite the finer materials. The screen may be attached directly to the bottom of an inner working casing or sealed to the protective casing by means of a lead packer or other commercially manufactured seal. The bottom of the screen should be closed with a plug of cement or the material of which the screen is made.

Natural sand and gravel wells are suitable for coarser grained materials and deposits which contain materials with a good range of grain size.

Components of a natural sand and gravel well and of a gravel-packed and rock well are illustrated in Figure 5.

Gravel-Packed Wells

The main components of gravel-packed wells are an outer protective casing, an inner working casing, a well screen set opposite the water-bearing formation and a gravel pack of clean washed gravel introduced around the outside of the well screen.

The protective casing extends from above the surface of the ground to or into the water-bearing formation.

The working casing is attached to the top of the well screen by a welded joint or a threaded coupling and extends upwards either to a point above the surface of the ground or to a point well above the bottom of the protective casing. In order to reduce corrosion the bottom portion of the working casing may be of the same metal as the well screen.

As is the case in a natural sand and gravel well, if the water-bearing formation is thick, blank sections of pipe may be set opposite the finer-grained portions of the aquifer. The screen is attached directly to the bottom of the working casing and the bottom of the screen is sealed with a plug of cement or the metal of which the screen is made.

The gravel in the gravel pack should be composed of well-rounded particles which have been washed and sized. The size of the gravel should be selected carefully with reference to the character of the water-bearing formation opposite the screen to ensure a sand-free water supply. Silica gravel has the best resistance to corrosion and is the material most commonly used in gravel-packed wells.

Gravel-packed wells are used not only for coarser-grained materials and deposits which contain materials with a range of grain size, but also for finer-grained gravels and sands that have little variation in grain sizes.

Rock Wells

Rock wells are dependable sources of supply for many municipal waterworks systems. The main problem in constructing a rock well is to provide a good seal between the protective casing and the rock to prevent the entry into the well of clay,

silt, and other fine particles from the overburden formations above the bedrock. This problem is more difficult when the materials directly on top of the bedrock are water-bearing silts, sands and gravels.

Most rock wells consist of a single protective casing extending from above surface to or into the top of the water-bearing formation.

The main methods used to seal the casing to the bedrock are by driving casing equipped with a drive shoe into the bedrock surface or by grouting an annular space between the casing and the rock in the upper portion of the bedrock formations. If these methods do not prevent the entry of overburden materials it may be possible to install a liner inside the protective casing which will extend below the bottom of the protective casing and be sealed to the rock portion of the well by a lead or other commercially manufactured packer. Cement grout may be introduced in the annular space between the liner and the bedrock.

Flowing Wells

Great care must be exercised in construction wells which end in artesian formations that possess sufficient pressure to flow above the surface of the ground. In the construction of such wells the initial drilling operations should extend into, but not through, the impermeable formation confining the water under artesian head. Then the protective casing should be installed and grout pumped into the annular space between the casing and the walls of the hole. Ample time should be allowed for the grout to set before drilling proceeds into the artesian formation. The drilling operations into the artesian formations are continued in a normal manner.

Water Quality

The water from many wells obtaining water from sand and gravel deposits has an iron content in excess of the recommended maximum of 0.3 ppm. This is the most common quality problem encountered in sand and gravel aquifers. Such water requires iron-removal treatment to ensure satisfied customers.

Rock wells present a greater variety of quality problems which should be determined during the pumping tests. Care should be exercised to be sure that the water wherever possible does not have a chloride content in excess of 250 ppm. The water from rock wells in Ontario generally is very hard and in nearly all cases no treatment is provided for the hardness. Quality problems which may require treatment are high contents of hydrogen sulphide or iron or a combination of these. Coliform bacteria may move considerable distances through bedrock formations from locations where the bedrock is close to surface to the sites of municipal wells thereby requiring chlorination treatment for the well water.

The advantages common to most well supplies are constant low temperature, freedom from turbidity and colour problems and general freedom from taste and odour problems.

Wells should be provided with a sanitary seal of cement grout or concrete extending from the land surface to a sufficient depth to prevent the seepage of surface water or other contaminating materials down the outside of the casing into the water-bearing formation.

Testing for Capacity

Discharge

In all tests, the discharge of the pumped well should be maintained at one or more constant rate throughout the test period. If more than one rate is used, the change should be an abrupt step from one rate to another. If the step discharge test is used, the period of pumping for each step should be sufficient to provide the basis for extrapolating water level trends from each past period.

The measurement of discharge may be made by any suitable device that limits the error to less than five percent. Prior to, during and after the test, the pumping from nearby wells which tap the formation being tested, should be stabilized if possible. If the regulation of pumping from outlying wells is not practical, records of their operation should be maintained.

### Water Level

The observation of drawdown in the pumped well and observation wells should be made with a steel tape or electrical device. Readings should be taken to the nearest hundredth of a foot during the period the well is pumped and also during recovery after the pump has been shutdown.

Prior to the performance of the test, each observation well should be tested to determine its sensitivity to water fluctuations within the aquifer. If the observation wells are not sensitive the condition should be rectified by further development.

The spacing of observation wells relative to the pumped well should be based on a knowledge of the geology, the transmission and storage properties of the aquifer to be tested, the duration of pumping and the location of nearby pumped wells.

### Timing of Pumping Tests

The timing of water-level measurements within the test period are of particular importance. The amount of water level decline at each observation well may be as great during the interval between the first and second minute after starting the test as during the interval from 1000 to 2000 minutes. The times of measurement should be very closely spaced at the start of the test or after each change in rate and should decrease in frequency as time progresses.

### Analysis of Pumping Test Data

Properly conducted and interpreted, the pumping test provides the means of obtaining data on the ground-water hydrology within the area surrounding the well that is being tested. The information furnishes the basic data for the selection of well equipment. An economic study can be made of the relative importance of diameter, spacing and distribution of wells in any aquifer. The amount of interference, the effect on adjoining wells, and the long-range performance of the well can be predicted, (see Figure 6).

## WATER QUALITY

Water moving through the atmosphere and the soil particles comes into contact with many soluble materials. These form chemical compounds, or salts, which are contained in solution.

Some rocks are more soluble than others. Granites and other igneous rocks are relatively insoluble but limestones, gypsum, and dolomite can be quite soluble. Over long periods of time, considerable amounts of calcium carbonate or sulphate are taken into solution from these rocks.

The hardness of water is due to the presence of bicarbonate and carbonate salts of calcium and magnesium and the alkaline-earth sulphates,chlorides, etc. The former contribute to the "carbonate" or "temporary" hardness and the latter to the "non-carbonate" or "permanent" hardness.

Ground water is usually very hard. A hardness scale in common use is as follows:

| | Hardness |
|---|---|
| Soft water | 0 - 60 ppm of Ca $CO_3$ |
| Medium or moderate hard water | 61 - 120 " " " " |
| Hard water | 121 - 180 " " " " |
| Very hard water | greater than 180 " " |

Depending on geological conditions, ground water may also contain amounts of hydrogen sulphide, salt, or iron.

GROUND WATER CONSERVATION

If the static level, or the level to which the water rises when the well is not being pumped, is gradually lowering in a well, it indicates that more water is being removed from the aquifer than is entering by natural recharge. The lowering of ground-water levels in the vicinity of pumped wells is not necessarily something to be alarmed about provided that at some time, the ever widening cone of depression finally includes sufficient recharge to balance the withdrawals. This may take place if the cone extends to intersect a body of surface water.

Just as in a surface reservoir or lake, it is perfectly feasible to draw on stored water during periods of drought with a consequent lowering of the water level, a similar withdrawal from storage from an aquifer would lower the level of the water table. The falling water tables we hear about are not unexpected during periods of low recharge; however, during wet years the storage tends to be replenished.

Water levels that continue to lower and do not show the effect of recharge indicate the mining of ground water. The continuation of such an over-draft will either lower the water level to the limit of economic lift or will exhaust the stored water.

It should be pointed out here that many aquifers can be recharged by artificial means either by means of pits or wells. The hydraulics of ground water is a very important study which increases our knowledge of the relationship of ground-water supplies to their extraction through wells.

Water conservation is equivalent to full use of water resources. In the past, insufficient thought and time has been devoted to the efficient use of ground water with the result that a number of areas are suffering from water shortages. A number of reasons for this situation are listed below:

1. Overconcentrations of industry and population.
2. Ground water withdrawal in excess of natural recharge.
3. Lack of artificial recharge.
4. Water wastage.
5. Location of communities or plant sites with inadequate planning.
6. Poor design of water consuming process equipment.

A number of the factors contributing to ground-water shortages result from lack of knowledge and unsound planning. On the other hand many industries and communities are located where circumstances beyond their control have caused water supply problems. It has been found that the long-term prediction of the demand for water is extremely uncertain. Nevertheless planning for the future is necessary.

By the study of water, by using operational measures for augmenting local supplies of ground water and by conservation, thorough efficient use and reuse can be developed. These procedures may not be sufficient in some circumstances and if this is the case, thought should be given to artificial recharge of ground-water reserves.

Artificial Ground-Water Recharge

Artificial recharge may be defined as the practice of increasing, by artificial means, the amount of water that enters ground-water reservoirs. The need for artificial recharge has occurred due to an increasing demand for fresh ground water. In a number of areas the withdrawal of ground water has exceeded natural recharge due to heavy well concentrations or low rates of natural recharge.

Some of the purposes for which artificial recharge is practised are as follows:

1. Supplement the quantity of ground water available.
2. Reduce or eliminate the decline in the water level of ground-water reservoirs.
3. Conserve and dispose of runoff and flood waters.
4. Store water to reduce costs of pumping and piping.
5. Reduce, prevent, or correct salt water intrusion.
6. Store clear, cool water in winter for use during the summer.
7. Allow heat exchange by diffusion through the ground.

Methods of Recharge

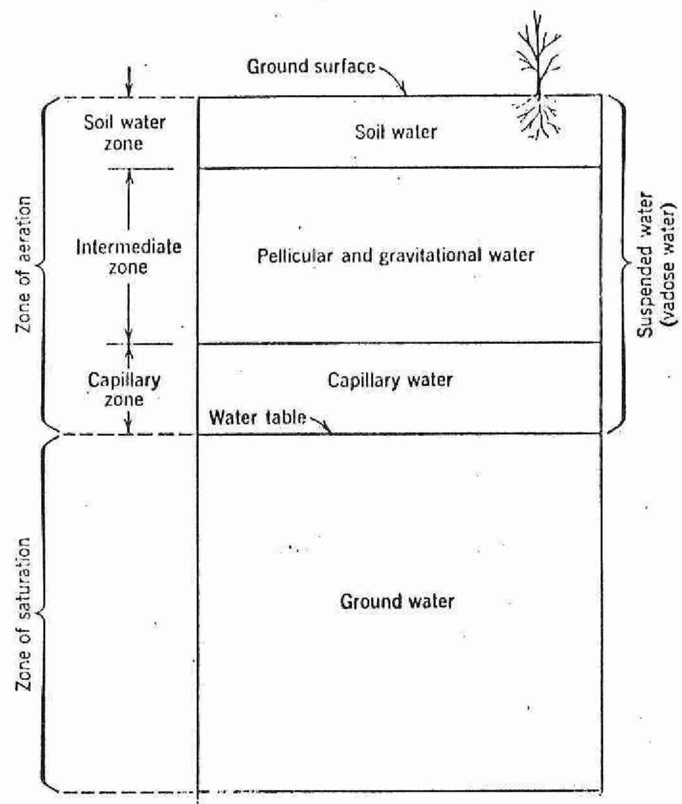
Water can be supplied to aquifers by means of recharge wells and natural and artificial recharge ponds. In the case of the recharge wells, water is allowed to flow by gravity or is pumped directly to the aquifer by means of a well or well system. Natural and artificially constructed recharge ponds allow surface water to accumulate and percolate downward through the ground to supplement the ground-water supplies.

Water that is to be used for artificial ground-water recharge may require treatment. The amount of treatment needed before the water can be allowed to enter the ground depends on the quality of the surface water to be recharged and the distance from the point of recharge to the nearest producing well.

Artificial recharge, where applicable, serves several valuable purposes that aid in solving many water-supply problems. Among the most important of these are the storing of runoff and flood waters for use when needed during dry seasons, the reducing or eliminating of effects of overdevelopment of ground water and the supplementing of existing ground-water supplies.

## CONCLUSIONS

There has been a pronounced increase in per capita consumption of water in recent years and this trend will probably continue in future. In order to prevent economic losses that result from overdevelopment of ground-water resources, the safe perennial yield of aquifers should be determined as accurately as possible prior to the maximum development of these resources. The development of water supplies must be maintained in balance with replenishment.




Zone of Rock Flowage

Figure 1 — Divisions of subsurface water.

THE HYDROLOGIC CYCLE

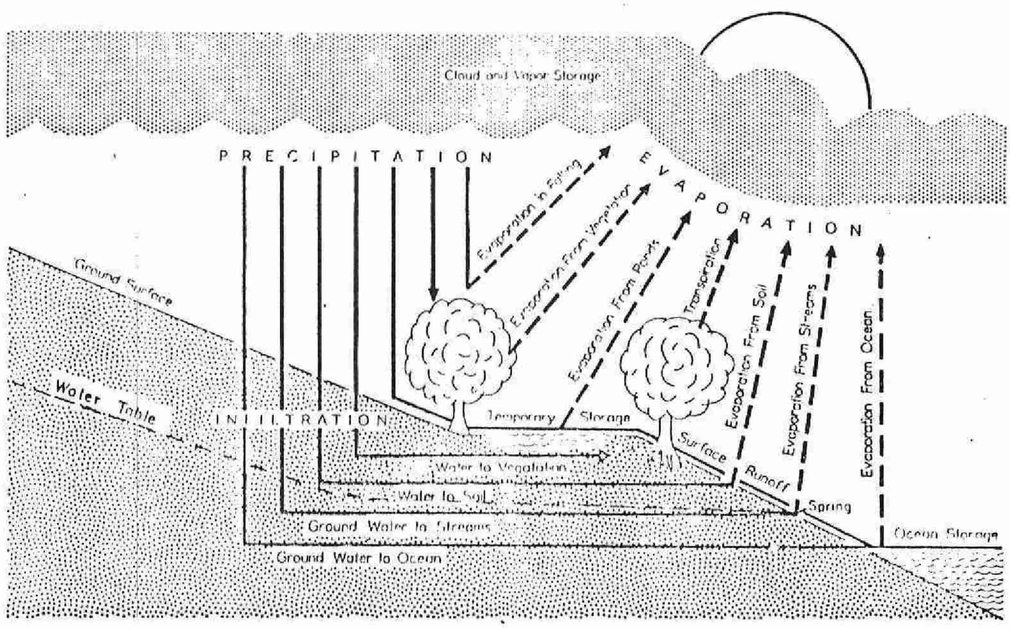



Figure 2

Courtesy of the U.S. Geological Survey

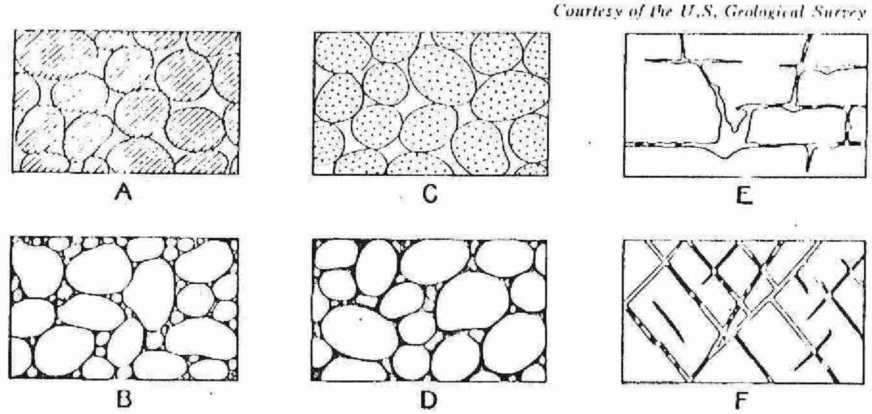



Figure 3—Diagram showing several types of rock interstices and the relations of rock texture to porosity.

A—Well-sorted sedimentary deposit having high porosity.
B—Poorly sorted sedimentary deposit having low porosity.
C—Well-sorted sedimentary deposit consisting of pebbles that are themselves porous; the deposit, as a whole, has a very high porosity.
D—Well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices.
E—Rock rendered porous by solution.
F—Rock rendered porous by fracturing.

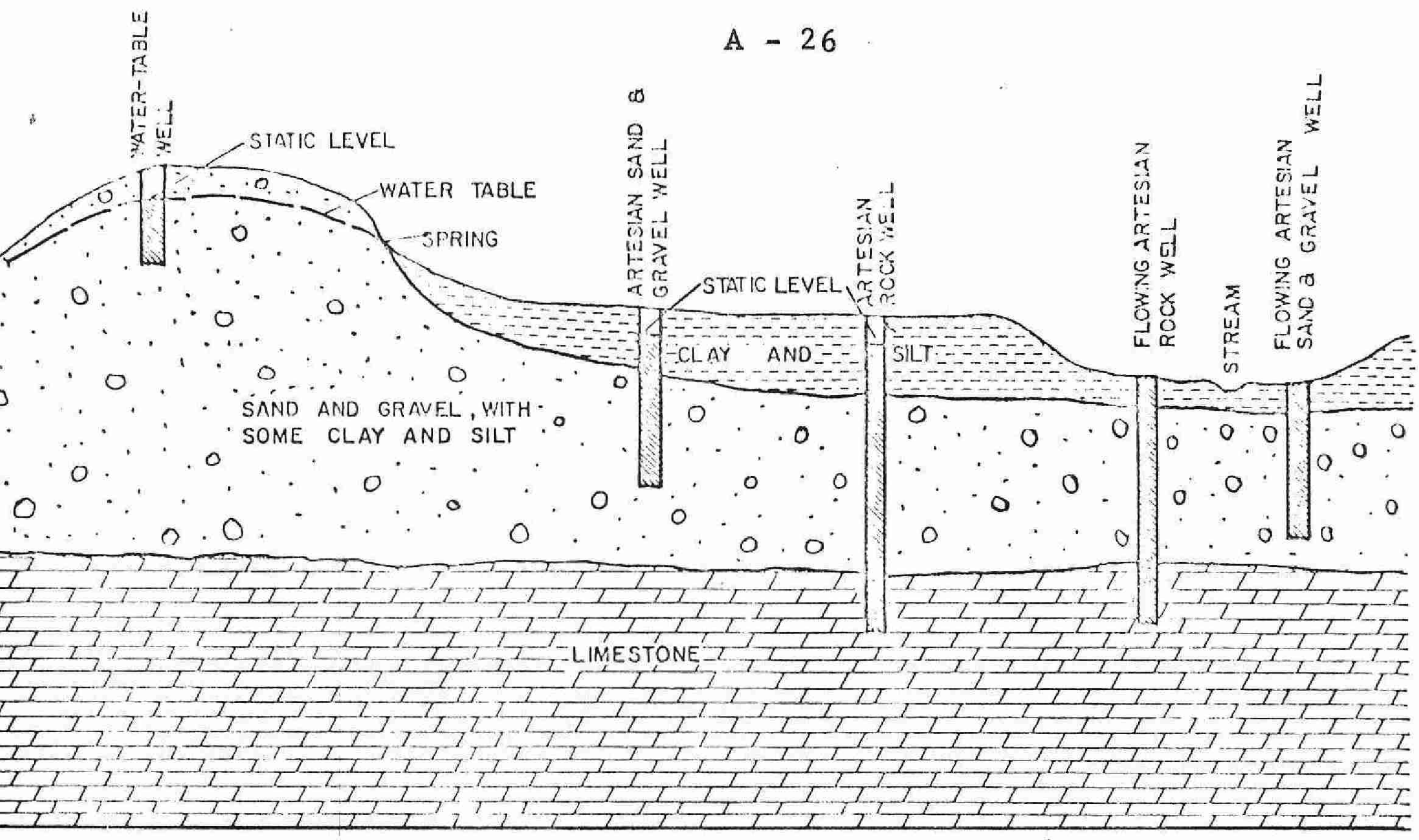



FIGURE 4. ILLUSTRATION OF WELLS COMPLETED IN OVERBURDEN AND BEDROCK FORMATIONS AND UNDER WATER-TABLE, ARTESIAN, AND FLOWING ARTESIAN CONDITIONS.

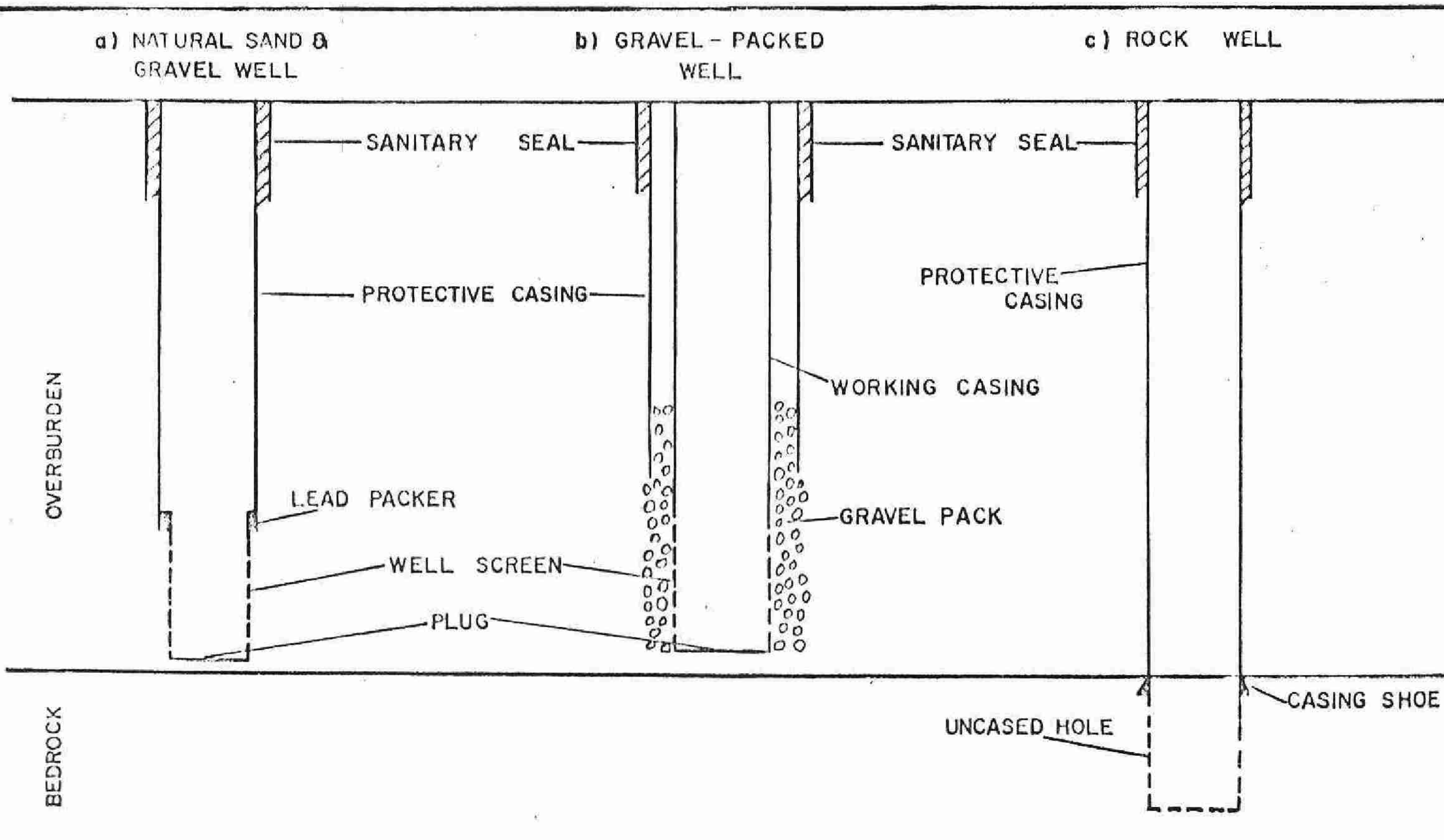



FIGURE 5. COMPONENTS OF SOME TYPICAL TYPES OF DRILLED WELLS.

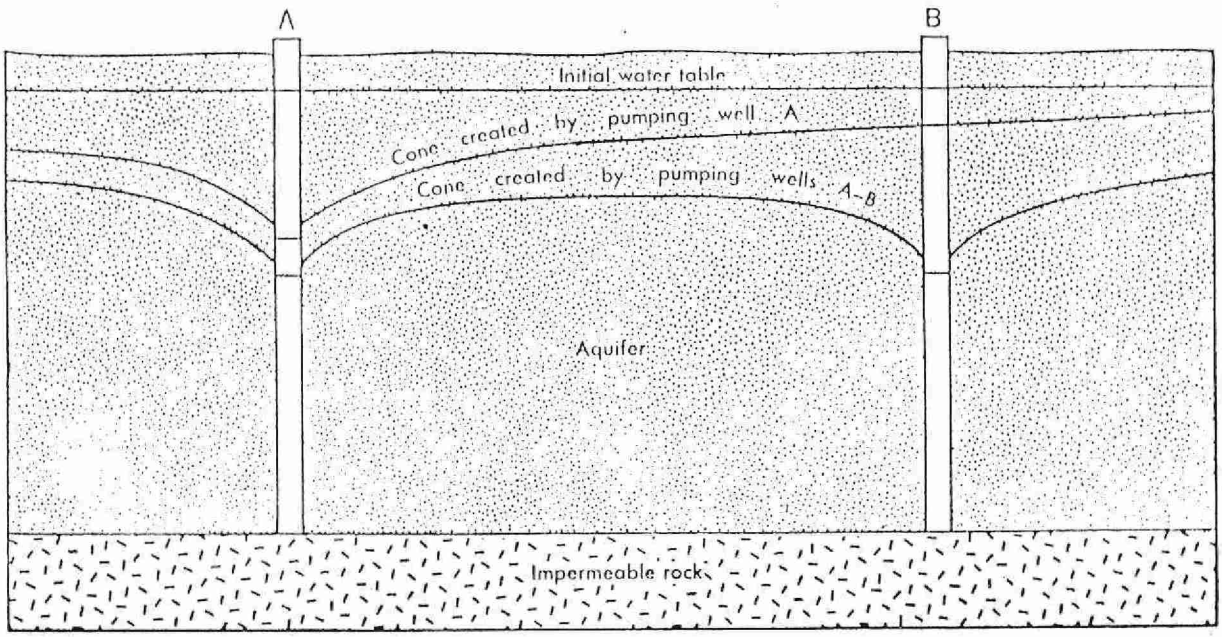



FIGURE 6 —*Cones of depression.*

# OPERATION AND MAINTENANCE OF MUNICIPAL WELLS

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## INTRODUCTION

About 60 percent of the water works systems in Ontario obtain their water supplies from wells. Wells therefore play a significant role in the water supply field and like any surface water supply, require certain attention if the maximum benefits are to be derived at the most economical means.

The operation and maintenance of a well are often taken lightly by well owners. The installation and maintenance of the pumping equipment is often given more attention because at least some of its working parts are above ground. A well, because it is underground and out of sight, is often overlooked until trouble occurs and demands immediate and perhaps costly action.

Certain general operating proceedures exist for wells as for surface water supplies and if followed, will tell the well owners how efficiently the well and pump are operating, how the water level in the ground water source is behaving, how adequate the supply is, and when action is required to rehabilitate the existing well or to install additional supplies into the system. Water wells cannot be expected to last forever, but systematic operation and preventative maintenance, properly worked out for the specific conditions in a locality, will assure a dependable source of supply and improve the overall performance and increase the life of the wells.

To properly operate or maintain a water well a person should have a working knowledge of the following:

1. the methods and materials used in constructing wells.

2. the local water-bearing formations or aquifers and their hydrologic characteristics.

3. the quality of ground water and its effect on well materials.

4. the causes of well troubles, how to recognize them and what can be done to eliminate them.

## WELL CONSTRUCTION

All water wells fall into two classes: overburden wells which obtain water from aquifers in unconsolidated formations lying above the bedrock and rock wells which obtain water from aquifers in the bedrock. The methods of construction differ greatly for the two types of wells. Consequently, the problems connected with well operation and maintenance are partially dependent on the type in use.

Overburden wells must depend on some kind of screening device below the casing to let the water, which flows through the pore spaces in the aquifer,into the wells. Well screens are intended to serve two purposes; to let water into the well with a minimum of friction loss and at the same time to hold back the particles of the formation in which the screen is placed. Many overburden well failures are due to poorly designed or inefficient well screens.

In contrast, rock wells depend on openings in the consolidated formations for their water supply and the extension of the drilled hole through the water-bearing zone is usually the only procedure needed. The number of openings intersected depends largely on chance and the amount of water yielded from different wells in the same formation may vary widely.

## HYDROLOGY

Regardless of the type of well, in the final analysis, several factors determine how much water can be obtained.

Over the long-term outlook, the yield depends on the replenishment of water by rainfall or other recharge to the aquifer. When more than the amount of recharge is withdrawn, there is a continuing decline in water level, which eventually could result in failure of the well.

The rate at which water can be withdrawn from a well annually in a particular aquifer depends on the hydrologic characteristics of the aquifer and the efficiency of the well. These can be determined only by means of pumping tests.

The measurements that are made in testing wells include the volume of water pumped per minute or per hour, the depth to the static level before pumping is started, the depth to the pumping level at one or more constant rates of pumpage, the recovery of the water level after pumping is stopped, and the length of time the well is pumped at each rate during the testing procedure. These measurements are particularly important as they not only furnish the basis for estimating the perennial yield of the well but they also determine the proper setting of the pump bowls.

## WATER QUALITY

The chemical constituents of ground water depend largely on the chemical nature of the formation itself, the rate of flow and the temperature. As a result the quality varies widely. The ideal is a chemically balanced water but usually ground water is either corrosive or scale forming. Either case will add to the deterioration rate of the well, unless methods and materials are employed which tend to retard their effects.

## PROBABLE CAUSES OF WELL FAILURE

From the preceding we can see that, although there are others, the three most common types of well failures are:

1. Failures due to faulty initial well design and construction. Such failures are indicated by difficulty in setting and operating pumping equipment, by partial or total collapse of the well casing, or by the pumping of large quantities of sand.

2. Failures due to pumping the ground-water reservoir at rates in excess of the rate of replenishment. Such failures are indicated by a continual lowering of the static level and pumping level in the well, as well as in the aquifer adjacent to it and are accompanied by a decrease in production.

3. Failures due to screens becoming clogged, incrusted or corroded in overburden wells and due to the openings in rock formations becoming plugged or incrusted. Such failures are indicated by increased drawdowns in the well accompanied by a falling off of capacity, while the water level in the adjacent formation remains the same, or by the continuous pumping of fine sand.

REMEDYING WELL TROUBLES

Well failures due to faulty design and construction are in the minority. Such failures are caused mostly by the use of cheap materials, poor construction methods, improperly designed screens as far as strength, diameter and slot size are concerned, poorly designed and placed gravel packs and poorly plugged bottoms. These failures usually give little or no warning.

Difficulties in setting and operating pumping equipment arise when casing diameters are too small to accomodate adequately the pump with the result that the slightest misalignment of the casing causes undue stresses in the pump column. As a general rule inside diameters of casings should be at least 2 inches larger than the pump.

Collapses of casings, while rare, are possible whenever casing is used that is not strong enough to withstand the vertical and lateral pressures that it will be subjected to under pumping. In actual practice collapses are prevented by using casing that is usually many times stronger than need be.

Poorly designed screens are the cause of many well failures. Slot sizes, lengths and diameters of screens should be selected with reference to the grain sizes in the aquifer and the designed capacity of the well. Slot sizes too small

for the formation are often specified in order to save development work. Improper selection of screens often results in excessive drawdown in the well because of increased friction losses.

Tremendous pressures are placed on bottom plugs and if the plugs are not carefully placed these pressures gradually loosen them, resulting in leakage of sand into the well.

Generally, failures of the kind I have just described occur in wells where it was desired to reduce costs to a minimum. This is false economy of the worst kind.

Well failures due to pumping the ground-water reservoir at rates in excess of the rate of replenishment are not infrequent and are usually the result of a general lack of knowledge on how to rate the yield of a well.

When a well is pumped, water is taken out of the underground reservoir by the reduction of pressure at the well, thus causing a flow towards the well. If the formation is not pumped excessively, the pumping level will eventually reach a point where replenishment to the aquifer is equal to withdrawal and equilibrium is established. On the other hand, if the formation is pumped excessively, the pumping level will continue to go down as long as the reservoir will supply water and will finally result in failure of the well. In actual cases what happens is that the pumping level gradually lowers in a well until it is too low for the pump to operate.

Overpumping results in low pumping levels thereby increasing operating costs as well as increasing the rate of clogging of well screens. Such conditions can be discovered only by means of performance records for the well and can be corrected only by regulating the pumping rate to conform with the rate of replenishment. This principle of well operation controls not only the quantity that can be safely pumped from one well but also the quantity of water that can be developed from a group of wells in a given area.

In order to avoid failures due to overpumping, the performance of all wells should be carefully recorded regularly, so that it can be determined when the maximum safe pumping rate has been reached.

Well failures due to inlet openings or screens becoming incrusted or corroded are probably in the majority.

Corrosion and incrustation are phenomena which are basically due to chemical changes in the water being pumped due to a reduction of pressure and an increase in the velocity of the water in the aquifer and entering the well. Corrosion of metals is a chemical action set up by the environment to which they are exposed, resulting in deterioration or eating away of the metal. Incrustation, on the other hand, is an accumulation of mineral salts or other extraneous matter in and immediately behind the openings in a well screen.

Corrosion of well screens is not as prevalent as incrustation but it is more harmful, because the metal itself is destroyed. Without considerable experience and some investigation it is difficult to recognize the type of corrosion involved, as there are at least six different forms.

The rate of corrosion is dependent on a number of factors, one of them being the rate of movement of water over the surface being corroded. To offset corrosion in wells and pumps, two general methods of approach are common; one is the use of protective coatings and the other the use of highly corrosion-resistant metals. Neither method has proved to be a wholly effective safeguard against corrosion.

Incrustation of well casings, openings, and screens is a deposition of materials in and around all metal parts of wells and pumps. These accumulations are made up largely of the bicarbonates and sulphates of calcium, magnesium, sodium and iron with a variety of lesser minerals. Other agents contributing to incrustation are iron bacteria and slime-forming organisms.

No way has yet been found to prevent or entirely remove these accumulations in and around well screens and pumps. Steps can be taken to retard such accumulations. One way is to design screens so that friction losses in the water passing through the screens and the aquifer are kept as small as possible. Another step is to lower the rate of pumping and increase the period of pumping. This will be effective if drawdown is materially reduced. Some well owners find it more economical to operate a large number of properly spaced wells, with less drawdown, than to try to obtain their requirements from a few wells having excessive drawdowns.

If it is suspected that incrustation is present, periodic cleaning of wells and pumps should be a regular item of maintenance if costly rehabilitation or well replacement is to be avoided.

The nature, construction and hydrologic characteristics of rock wells are different from overburden wells and the maintenance and operation of them is somewhat different. Mostly it is a question of good judgement coupled with experience.

Mechanically there is very little that can be done to maintain a deep rock well supply. Sometimes it is necessary to go into such wells for the purpose of keeping the fractures or solution channels open. If the drill hole has become partially filled with sand or rock debris it is cleaned out by bailing. Chemical treatment and surging are helpful in dissolving certain kinds of accumulations in the fractures.

One of the main causes of failure in rock wells is the lowering of the water level to a point at which it is no longer economical to pump the well. This, of course, can be avoided by the regulation of pumping rates to the amount that can be safely withdrawn annually.

## RECORDS TO BE KEPT

From the foregoing we can see that the keeping of accurate periodic records of pumpages, static levels, and pumping levels in wells would be essential and invaluable in any emergency which may arise. Such information would also be helpful in anticipating shortages due to increased demands or failure of wells and pumping equipment. If records are to be kept it is essential that the readings be taken accurately by the use of approved measuring devices and standard methods.

## METHODS OF MEASURING WATER LEVELS

For measuring a water level the common unit is the foot, though it is sometimes necessary to take the readings in other units and convert them to feet for recording.

To make readings to any water level the simplest way is to use a weighted, chalked steel tape. Readings taken in this manner are usually the most accurate. However, it is often difficult to get such a line down a well because of the manner in which the pump is installed. Portable electric depth gauges also fall into this category.

A satisfactory method and probably the most common is to use an airline and pressure gauge. This apparatus is inexpensive, easy to install and remove, and is generally accepted for all but the most accurate tests. It consists essentially of small diameter pipe or tubing extending from the surface to a point below the maximum expected pumping level. The line is usually fastened to the pump column with the bottom being at least 10 feet above the intake of the pump because high velocities will affect the readings. On top of the tubing or pipe is an ordinary altitude or pressure gauge to which is attached an ordinary tire pump or air pressure hose if available. In order to make accurate readings with this device it is necessary that the airline be air tight from one end to the other and that the exact vertical distance between the centre of the gauge and the open end of the airline be determined.

## METHOD OF USING AIRLINE

When the airline is installed it is full of water up to the level of the water in the well. When air is forced into the line, it creates a pressure which forces all of the water out of the lower end filling the line with air. If more air is then pumped in, air instead of water is expelled and it is not possible to increase the pressure further. The head of water above the lower end of the airline maintains this pressure, and the gauge shows the pressure or head required to balance the water pressure. If such a gauge is graduated in feet, it will register directly the amount of the airline that is submerged. The submerged portion is subtracted from the total length of the line to give the depth to the water level. To simplify the readings even further, a new type of gauge is now available and in common use today. It is simply a pressure gauge graduated in feet with the scale reversed. All that is required is that the needle pointer be set under zero pressure at the number corresponding to the length of the airline. Under pressure the pointer will indicate the exact depth to the water level.

For maintenance purposes water level readings should be taken daily, especially the pumping level. Static levels should be taken at least once a week. In each case the reading should be taken after the longest period of pumping or recovery, respectively.

## METHODS OF MEASURING QUANTITY

While the measurements of water levels are being made it is just as important that measurements of the quantity being pumped at those levels be made. Generally flow meters are standard equipment in most pumphouses. If they are not they should be. Records should include a daily reading of the total daily flow. It is periodically found necessary to retest a well for production especially if it is suspected that production has fallen off. During retesting wells for production, it is important that constant rates of flow be maintained. This can usually be done most accurately if the flow is measured while the water is being pumped to waste at the pumphouse. There are numerous methods for measuring the flow, some of these being Venturi meters, Pitot tubes, current meters, orifices, flow gauges, and weirs. Devices of this kind are easy to install but they must be installed correctly and the readings taken carefully.

The need for a compact, easily installed, and reasonably accurate measuring device has led to the general acceptance and use of the circular-orifice meter. The device consists of a sharp-edged circular orifice at the end of a horizontal discharge pipe. The orifice is from 1/2 to 3/4 of the diameter of the pipe. The pipe must be smooth internally and free of any obstructions for a distance of at least 6 feet from the orifice. The discharge pipe is tapped on the side to provide a connection for a rubber or plastic hose or glass tube so that the pressure or head in the discharge pipe can be measured at a distance of 2 feet from the orifice. The discharge pipe must be horizontal and the stream must fall free from the orifice. The orifice must be vertical and centred in the discharge pipe. The combination of pipe and orifice diameters for a given test should be such that the head measurement will be at least 3 times the diameter of the orifice.

Tables are available which give the discharge in gallons per minute through circular-orifice meters of various sizes corresponding to the heads observed in the manometer tube.

PROTECTIVE MEASURES

In operating wells there are a number of things that should be done to maintain and protect a ground-water supply. Some of these are as follows:

1. All wells should be located and constructed by men experienced in this type of work and who understand the occurrence and movement of ground water in the various water-bearing formations. Improper construction and improper rating have been the cause of many well failures.

2. All wells should be located so that they will not interfere seriously with other wells operating in the vicinity.

3. All wells and pumping equipment should be constructed of materials that will resist the corrosive and erosive action of the water being pumped, as well as the action of chemicals which may be used to remove accumulations.

4. All wells should be operated at their most economical and efficient point by equipping them with pumps properly designed for the characteristics of each well.

5. Water samples should be collected and analyzed regularly and periodically for chemical and bacteriological quality. The quality of the water may change slowly as the well is used. It may improve or it may get worse, depending on the geologic and hydrologic conditions of the area. Chemical analysis may indicate whether incrustation likely is occurring and what steps should be taken to prevent serious plugging of the well.

6. Last and possibly most important is the keeping of good records of well operation. Accurate records of the history of the well undoubtedly provide the soundest basis for deciding just what preventive maintenance procedures would likely be most worthwhile.

7. A carefully conducted pumping test carried out periodically in the prescribed manner is also advisable. Such tests, when interpreted in the light of good data on the past history and known changes, assist greatly in developing practical maintenance procedures.

## CONCLUSIONS

In conclusion we can see that good operation and maintenance of a well supply is as important as that of pumping equipment and are a responsibility of the owner which should not be taken lightly or ignored completely. If it is expected to get the most out of a well supply, good construction methods should be employed, proper pumping equipment installed, and adequate supervision provided.

Supervision is the responsibility of the water-well operator; if this is to be done properly he should inform himself regarding the wells under his care.

# SAFETY IN WELL OPERATION

Ray Norton

Safety Officer
Division of Plant Operations

Deep well operators in water works have natural hazards to their safety as well as hazards that are common to any building that contain stairs, ladders, electrical equipment with their control panels and machinery with their mooring shafts etc. These natural hazards are in the form of natural gas C.H.4 found in some water supply areas and water containing sulfer or Hydrogen Sulfide gas $H_2S$.

## Natural gas, Methane $CH_4$ in water

The presence of natural gas in the water being pumped into the distribution system can and has in the past created dangerous problems for the operators. To name a few of these problems the most predominate among them are the explosive conditions that can develop at the lower or pump floor level. The gas being carried by the water can leak into the pump room through the packing glands of the pumps and mixing with the air in the room. If sufficient gas is present then the moment the electric motor starts up on automatic control there is an explosion You may say that to consider such conditions being developed to a level where an explosion would occur is carrying a remote possibility to the extreme.

Perhaps so, but in answer to that opinion the operator cannot afford to ignore any such possibility regardless of how remote it may seem because it has happened and can again.

Natural gas leaking into the lower levels of a pumping station or deep well in such small quantities that an explosive level may never be reached will create other conditions just as dangerous to the operator. Natural gas is not known to be toxic to humans but it will react with the oxygen in the body to a level where it will not support life (see chart) Hydrogen gas (see chart) as per $CH_4$.

Hydrogen Sulfide $H_2S$

To be found in water supplied by wells containing sulfer, and wells fed by pipe intakes from certain areas of Lake Erie and Lake Ontario the gas is developed mostly by the settling out and decaying of algae in the lake water.

This gas is the most dangerous of all gases found in water or waste water treatment plants and pumping stations.

Not only can it develop explosive conditions as described for natural gas it has a much greater explosive range than natural gas. 14 to 45% to air by volume as compared to natural gas 5 to 15% to air by volume.

It too will reduce the oxygen content of an enclosed space but it has one more potentional hazard than natural gas, it is extremely poisonous. It can be detected by its generally described odour of rotten eggs but generally it just stinks. This odour is noticed only for a short time as the concentration increases the smell is less noticeable and disappears quickly, there is a tendency to think the gas has gone but this is not so. Just the ability to smell it has gone (see chart). When $H_2S$ is present in even small quantities it usually leaves evidence throughout the building.

Brass or copper pipe will turn a dirty black; painted surfaces will streak with the same colour. Heavier concentrations of the gas will destroy concrete. Iron ladder rungs and steel manhole covers will crumble, the gas mixed with air and moisture converts to sulfuric acid.

Knowing the hazards of these gases it is evident that the operator when he encounters odours at the entrance or in a deep well or pumping station he will not go any further but will make a hasty retreat to the outside.

He must remain outside until the well or station can be ventilated sufficiently to remove or reduce any gas accumulation below any hazardous limits. Under no circumstances must he allow any other person to enter the well or station.

Section 12, Subsections 2 and 3 - Industrial Safety Act, Department of Labour. (Entry into confined spaces) covers the aforementioned conditions.

Every employer shall ensure that any tank, vat, chamber, pit, pipe, flue or other confined space that may be entered by any person,

a) has a suitable man-hole or other means of easy egress from all accessible parts of the confined space; and

b) is safe for entry.

Where gases, vapours, mists, fumes or dusts that are likely to be dangerous to a person are present in any of the confined spaces referred to in subsection 2, or there is in the confined space a deficiency of oxygen or a temperature that is likely to be dangerous to a person, the employer shall ensure that no person enters the space unless,

a) every practicable step has been taken to remove from the confined space such gases, vapours, mists, fumes or dusts;

b) effective steps have been taken to prevent entry into the confined space of additional quantities of such gases, vapours, mists, fumes or dusts;

c) the confined space has been competently tested and found safe for entry without the use of a breathing apparatus; and

d) ventilation adequate for the safety of any person therein is provided.

Subregulation 12 (2)

covers the employer's obligation to:

a) provide means of access

b) ensure safety for entry

A confined space is safe for entry by either:

a) Inherent design so that the confined space is safe to enter.

b) Test that the confined space is safe to enter, or

c) Rendering the confined space safe to enter and confirming the fact by tests.

Subregulation 12 (3)

covers the procedure to render a hazardous space safe for entry.

a) Testing a potentially hazardous space to see whether it is hazardous or not,

b) Removal, in a safe manner, of all hazardous material from the confined space,

c) Taking positive steps for the preventing re-entry of the hazardous materials into the space,

d) Testing that the confined space is safe to enter, and,

e) Ventilating of the confined space.

f) The ventilation referred to in this subregulation is that required for normal breathing purposes and not for the prevention of hazard buildup.

If, at any time, while stationed at the top of a deep well or manhole you notice that the man or men in the well or manhole have collapsed do not I repeat do not climb down to render assistance unless you are equipped or can be equipped with a self-contained breathing apparatus with full face piece and have with you a safety belt of parachute design and a strong rope.

There have been many men lose their lives trying to rescue a man already dead.

Electrical Safety

Each employee shall be qualified as to experience and general knowledge to perform the particular work to which he is assigned.

Study the job carefully to determine all of the hazards present and to see that all necessary safeguards and safety devices are provided for safe working conditions.

Examine all safety devices before they are used to make sure that they are in good condition.

Provide safeguards such as danger signs, barricades, etc., for the safety of persons working close to but not engaged in the electrical work.

Plan safety into each job. Orderliness and good housekeeping are essential for your safety and the safety of others.

In all cases where work is hazardous and is being performed on or close to, live conductors or apparatus, at least two men shall work together. When it is necessary for one of the men to leave for any reason the other workman may perform any other work outside of the hazardous area until the first man returns.

Do not do this work while alone.

Consider the results of each act. There is no reason for you to take chances that will endanger yourself or others.

Be careful always. Place yourself in a safe position while working to avoid falling, tripping, slipping or moving backwards against live parts.

Satisfy yourself you are working under safe conditions, the care exercised by others can not be relied upon.

Exercise caution. Consider every circuit to be alive. Respect all sources of power as potentially dangerous.

Wear close fitting clothing, keep sleeves rolled down, avoid wearing unnecessary articles while working on or close to live circuits or apparatus.

Use only approved types of rubber or leather gloves.

Use rubber mats when working on any electrical control panel or switch and disconnect boxes.

Protect yourself by placing an insulated medium between you and ground or grounded apparatus to keep any part of your body from providing a path for electrical current when working on conductors or apparatus that may be energized.

Take extra precautions when working on damp or wet surfaces. If necessary use additional insulation to prevent any part of your body coming into contact with the damp or wet surfaces.

Determine the operating condition of the circuit before opening or closing any switch. This precaution is to ensure your protection in case of a faulty circuit and to protect other workmen in case they are exposed.

Open or close the switch with a firm positive manner using sufficient force to make or break full contact of the blades quickly. This will prevent unnecessary heating or arcing when the blades make or break contact.

Open switches completely, close switches completely. Switches left in a partly open position may arc or cause a flash-over with damaging results to the switch and possible injuries to the operator.

Open switches fully before removing fuses. To remove a fuse from a circuit carrying a field current without opening the switch is particularly hazardous.

Use an approved low-voltage fuse puller to remove fuses on a circuit of less than 500 volts (where no switch is provided) whether a disconnect is provided or not.

Remove fuses by breaking contact with the hot side of the circuit first. Use the reverse procedure when replacing the fuses. Insert the fuse in the cold terminal first.

## Chlorine

### Safety Methods of Handling Chlorine

Chlorine in one of the work-horse chemicals of industry and in any discussion of the subject some of the properties of the chemicals should be considered first.

Despite the fact that chlorine handling equipment is well designed, a fact well-proven by the number of people who have been handling chlorine for many years without an accident, it must be recognized that chlorine is a potential killer if equipment becomes defective or people become careless.

There is no such thing as a foolproof method of handling chlorine. Therefore, we will deal with the potential hazards which can be avoided or eliminated if the lethal properties of chlorine are recognized.

By itself, chlorine is neither explosive nor flammable, but it will support combustion.

For example, steel at a temperature of 483°F will ignite in the presence of chlorine and burn quite readily. Other metals will act similarly at slightly higher temperatures.

The least detectable amount of chlorine in the atmosphere is about 3 1/2 ppm. The maximum amount that can be inhaled for one hour without serious effects is about four (4) ppm. At fifteen (15) ppm, chlorine will cause irritation of the throat; at thirty (30) ppm, it will cause serious spells and at forty (40) to sixty (60) ppm, it is extremely dangerous for one half hour exposure. A few breaths of air containing 1,000 ppm would be lethal.

Essential Items Required

1. A two-wheeled chlorine cylinder hand truck.

2. A 10 or 15 minute air pack of approved design.

3. Where one-ton cylinders are in use, a self-contained air pack with a full face piece of approved design and make, and with a spare cylinder.

4. A wall mounted steel cabinet with glass panels for storing the air pack.

5. Canvas or cotton gloves coated with waterproof plastic.

6. A bottle of five percent concentrated ammonia for detecting chlorine leaks (not household ammonia).

7. Signs - "Turn on Exhaust Fan Before Entering".

Chlorine is shipped in three types of containers, 150 pound cylinders, ton cylinders and tank cars. The 150 pound container is the more familiar item. These cylinders are equipped with a single Chlorine Institute standard cylinder valve which has a brass body and a Monel stem. There is a packing gland containing two rings of packing and a fusible plug. The fusible plug is located on the side of the valve opposite the out-let and is designed to release pressure in the cylinder should the cylinder temperature rise above 160°F on the outside.

The standard way of making a connection to this valve is with a yoke clamp, adaptor and a small head gasket. These three items are supplied free by the chlorine suppliers. When connecting a cylinder to the chlorinating system, the following steps shall be followed.

1. Secure the cylinder to a building column or a solid upright support.

2. Remove the protective bonnet. If the cylinder has been exposed to the weather for a long time the threads at the base of the bonnet may have become corroded, in which case a few smart raps on opposite sides of the bonnet will loosen it so that it may be unscrewed easily.

3. Remove the brass outlet cap and any foreign matter which may be in the valve outlet recess. When removing this brass outlet cap, stand to one side and remove it carefully, as there is the possibility of some chlorine being trapped under this cap.

4. Check outlet recess for old lead washer, a 3" nail can be used.

5. Place a new lead washer in the outlet recess.

6. Place a clamp over the valve and inset the adaptor in the outlet recess and then fitting the adaptor in the clamp slot, tighten the clamp screw.

After the valve is opened and the flow of chlorine adjusted you should check that the packing gland is tightened down. A check of the connections should also be made, with an ammonia bottle, for any leaks. The maximum discharge rate for a single 150 pound cylinder is about two or three pounds per hour.

When discharging gaseous chlorine, a cylinder is actually re-frigerating itself. As the liquid chlorine

inside the cylinder vapourizes, it takes up heat from the surroundings. No doubt you have noted that when a cylinder is nearly empty, frost forms on the outside of the cylinder. This acts as an insulation and reduces the amount of heat that the cylinder can get from its surroundings. This condition lowers the chlorine pressure considerably. The frost may be removed by scraping, or by circulating warm air around the cylinder with a small fan. Do not, under any circumstances, apply hot water or external heat to a cylinder to speed up the supply of chlorine. This is an extremely dangerous practice. There is another simple method for getting around this slow delivery of chlorine at the end of the cylinder and that is to connect another cylinder to a manifold. When the first cylinder becomes covered with frost, shut it off and use the fresh cylinder until the first cylinder has warmed up to room temperature and the pressure has been restored.

The only reliable method of determining the contents of a cylinder, is by weighing. The pressure in a cylinder depends on the temperature, not upon the amount of chlorine in the container. When convenient, it is recommended that the cylinder stand on a scale throughout the entire period of discharge. In any event, the only sure method of determining whether or not the cylinder is empty is to weigh the container and check its weight with the tare weight stamped on the cylinder's shoulder.

Operating Safety Instructions

1. A self contained air pack must be worn when it is necessary to locate and stop small leaks in the piping or when making any repairs or adjustments or leaking equipment.

2. Wear plastic coated gloves when changing cylinders.

3. When connecting the piping from the cylinders to the chlorine machine or whenever it is necessary to break a connection and recouple it, a new lead or fibre washer must be used each time.

4. Do not lift a cylinder (150 lbs) up onto the scales. Use a ramp.

5. Whenever possible, two men should be present when changing chlorine cylinders.

6. A self-contained air breathing unit must not be used unless the air cylinder is fully charged. Cylinders must be completely recharged after each use.

7. When a leak occurs in a chlorinator room, do not open or leave open any doors leading into any other part of the building. Only doors to the outside should be opened.

8. Water should never be applied to a chlorine leak because of the added corrosive action created by the water and chlorine mixture.

9. The chlorine exhaust fan must be turned on at all times when entering the chlorine room, whether for a routine check or for servicing or repairing leaking equipment while wearing a mask.

10. In all cases where the concentration of the chlorine gas in the air is unknown, a self-contained air pack must be worn.

11. Do not start up or operate a chlorinator or turn on a chlorine cylinder unless adequate equipment (air pack respirator) is on hand in the chlorine room area.

12. All persons using the gas protective equipment must be trained in its use and maintenance.

13. All removable parts of the chlorinator such as cylinder clamps, metal hose connections, couplings, headers, valves etc., should be removed at the end of the chlorinating season, cleaned and inspected, and worn and damaged pieces replaced.

15. When using chlorinated powder or chlorine of lime for dusting etc., a proper type of eye shield and gloves must be worn.

The piping from the cylinders to the header located on the wall or to the chlorine machine must have an inverted loop of not less than 10" in diameter in its length. The loop acts as a flexible coupling.

General Safety Practices

DO NOT

a) Grease or oil or attempt to service any machinery while it is in operation. Pumps on automatic control must be locked out and key carried by the operator during servicing.

b) Make any adjustments to operating machinery while alone, if it is necessary to run the unit to properly adjust it, a second man must be present and be beside the stop and go switch.

c) Work around electrical panels, disconnects or switches alone. Enter any crawl space under flooring for any purpose until the area has been ventilated a second man should be present.

d) Service pumps and shafts in the dry wells of pumping stations, and in plants where the pumps and shafts are less than three feet apart, without shutting off all pumps and locking them out.

Under no circumstances must an operator attempt to grease or service pump shafting while standing on beams, piping, loose planks, guard rails, or by leaning out, over or through guard rails. If a ladder must be used, then a second man must be present to hold the ladder steady and for any other assistance required of him.

## OUTSIDE PLANT WORKS

a) Walkways must be kept clear of loose objects such as pails, shovels, loose rope etc.

b) Grease and oil should be wiped up immediately, icy walks can be salted or sanded.

c) All tools must be picked up, cleaned and returned to their storage area.

d) When it is necessary to use tools in an empty tank or manhole etc., they should be lowered in a pail on a rope and removed in the same way. Brooms and shovels can also be transported by rope. Do not attempt to climb up and down ladders with your hands full of tools, shovels etc.

e) Don't overload yourself when using stairways, keep your load small enough to be able to see over it and have one hand free to use the hand rail.

f) Do not attempt to climp up or down a ladder or over a railing while handling a hose under pressure.

g) When washing down the floor of any tank, be sure you wear hip wader rubber boots with good treaded soles, do not wear rubber boots with worn and smooth soles and heels.

h) When working in a narrow or confined passage where grit or sludge accumulates, wear the appropriate rubber clothing provided.

i) Whenever working below ground level (in tanks, manholes, etc.) or under scaffolding, hard hats shall be worn.

j) Do not hang clothes on electrical disconnect handles, light switches or control panel knobs.

k) Manhole covers and trap doors to wells must be replaced, and/or closed, after using or protected by guard rails if necessary to leave open.

l) The proper tool must be used when removing or replacing manhole covers, do not attempt to move or close a manhole cover with your hands.

# GENERAL SAFETY PRACTICES

There are four key steps to preventing accidents.

1. Keeping injury records.
2. Locating safety hazards.
3. Making equipment, plant layout and work methods safe.
4. Controlling work habits.

## MISCELLANEOUS SAFETY HINTS

1. Providing personal protective equipment is the primary step in an accident prevention program. Such equipment includes protection against hazards to eyes, face, feet, hands, head and respiratory organs.
2. First aid has an important bearing on prevention of injuries because men versed in first aid are less susceptible to accidents than those not so prepared.
3. New employees should be thoroughly instructed, not only as to duties of the job, but also about plant safety requirements, personal safety protection and safe operating practices.
4. Lifting, lowering and handling equipment should be done safely and the proper procedures applied to such items as wheelbarrows, hand trucks, scaffolds and ladders.
5. Falls can be prevented by following good safety practices with respect to walkways, stairways, handrails, machine guards and by walking not running.

6. Tools should be handled in accord with the basic rules of safety, particularly such tools as axes and hammers, chisels and punches, files, picks, saws, screwdrivers, shovels, and spaces, wrenches and, of course, all portable power tools. Safe practices also exist for such operations as metallizing, sand blasting, grinding with wheels and soldering.

7. Storerooms and stock rooms should be designed to provide proper storage which will contribute to safe handling of materials, particularly drums.

8. Fire protection is an important part of every safety program. Flammable materials within buildings should be kept in approved safety cans only. Fire extinguishers should be located outside of all workrooms. The local fire department should be consulted for advice.

9. Pumping stations need safe practices too, particularly with respect to oiling, repairs, solvents, guard rails around machines, electrical switch panels and transformer stations.

10. Diesel and gasoline engines are especially important in a safety program. Safe practices are necessary with respect to gasoline and oil storage, gear shifts, exhausts and repairs. Gasoline should not be stored within a building except in an approved safety can. Particular care should be taken during repair work on fuel systems of gasoline engines. The shut-off valve from the tank should be closed and adequate ventilation provided while draining the fuel system.

11. Chemical handling and storage require both common sense and safe practices. Each

chemical has its own safe practice rules, particularly (chlorine, ferric chloride and lime). Some chemicals require personal protective equipment when being handled. All may require first aid in the case of unsafe practices.

ONTARIO
DEPARTMENT OF LABOUR
ENGINEERING SERVICES BRANCH

ENGINEERING
DATA SHEET No. 5-3

# STORAGE AND USE OF CHLORINE

**Introduction**

Chlorine has wide use in industry. 150 lb. cylinders are commonly used. Where usage exceeds 150 lbs. daily, one-ton containers have been introduced to minimize handling.

**Properties**

Chlorine liquid has a specific gravity of 1.47 (water = 1)

Chlorine gas has a density of 2.49 (air = 1)

One volume of liquid chlorine gives off 456.8 volumes of gaseous chlorine at 32°F and 1 atmosphere pressure.

One pound of liquid chlorine is equivalent to 4.98 cubic feet of gaseous chlorine at 32°F and 1 atmosphere pressure.

Dry chlorine does not corrode steel or common metals at ordinary temperatures. In the presence of moisture, hydrochloric acid is formed causing corrosion.

**Characteristics**

Chlorine is non inflammable, and is a powerful respiratory irritant.

**1. Location**

(a) Storage should preferably be in an isolated building or in a room without direct access to a factory area. Construction should be of fire-resistive material and the building or room should have concrete floors and good drainage.

(b) Ton containers shall be stored on their sides on level racks, e.g. parallel "I" beams. There should not be less than 4 in. and not more than 8 in. air space between the container and grade.

(c) Chlorine should not be stored below ground level.

(d) Chlorine should not be stored with combustible materials.

(e) The container shall be protected against excessive external heat sources, dampness and mechanical damage. Outside storage should be sheltered from the direct rays of the sun.

(f) Separate storage space shall be provided for full and empty containers.

(g) Storage areas shall not be located in areas where escaping gas could enter a ventilating system.

(h) Chlorine storage areas shall be clearly marked "Danger! Chlorine Storage!"

(i) The scale room should be adjacent to the storage area and be of fire resistive construction.

**2. Exits**

The exit doors shall be hinged to open outwardly. There shall be two or more exits if the distance of travel to an exit exceeds 15 ft.

The distance of travel to the nearest of two or more exits shall not exceed 75 ft.

**3. Ventilation**

(a) Continuous mechanical ventilation at the rate of 3 air changes per hour shall be provided, or, screened openings to the outdoors shall be provided within 6 inches of the floor in the ratio of 1 sq. ft. per 500 sq. ft. of floor area. Similar openings shall be provided in or near the ceiling. The openings shall be distributed to produce the maximum air circulation across the floor.

(b) Provision for emergency mechanical ventilation should be made sufficient to produce 30 air changes an hour taking suction at a maximum of 3'-0" above floor level.

**4. Protective Equipment**

(a) Emergency canister gas masks of a type approved for chlorine service by

the United States Bureau of Mines shall be readily available where chlorine is being stored or used. The gas masks shall be kept in dust-tight cabinets and the cabinets locked in a conspicuous location outside the area of probable contamination.

(b) Only self-contained or air-supplied types of respiratory protective equipment shall be used where the chlorine concentration may be above 1 per cent (10,000 p.pm.). Gas masks are of no use in these cases.

(c) Protective goggles, aprons, gloves and safety shoes shall be available for persons loading, storing, or handling chlorine.

(d) Deluge type safety showers and eye wash fountains shall be available in case of accident. These shall be located as near as possible but outside the area of probable contamination.

**5. Chlorine Leaks**

A plan of action shall be prepared to deal with emergency leaks. A chlorine tool kit recommended by the supplier shall be available.

**6. First-Aid**

Remove the affected person from the contaminated area. Keep him warm and quiet. If the victim is conscious, do everything possible to discourage coughing. Oxygen is of great value. Even in mild cases, inhalation of oxygen relieves chest irritation. In severe exposure cases, oxygen should be administered until the victim is able to breathe easily. Contaminated clothing should be removed and contaminated body areas flushed with water. If breathing seems to have stopped or has ceased, apply artificial respiration without delay along with oxygen. The services of a physician should be obtained as quickly as possible.

**7. Chlorine Disposal**

Chlorine may be absorbed in solutions of caustic soda, soda ash, or hydrated lime. A solution of caustic soda absorbs chlorine most readily.

| RECOMMENDED SOLUTIONS FOR ABSORBING CHLORINE (ONE-TON CONTAINER) | |
|---|---|
| ABSORBING CHEMICAL | WATER |
| Caustic Soda — 2500 lb. | 800 gallons. |
| Soda Ash — 6000 lb. | 2000 gallons |
| Hydrated Lime — 2500 lb. | 2500 gallons |

ONTARIO
DEPARTMENT OF LABOUR

ENGINEERING
DATA SHEET No. 8-14

June 6, 1963

## MEMORANDUM TO INSPECTORS

### ENTRY INTO TANKS AND OTHER CONFINED SPACES

General

Entry into tanks and other confined spaces by workers is necessary for many industrial operations. From experience, it is well known that entry into such confined spaces may present a hazard to the worker. There are many recent examples of multiple fatalities from such work, e.g., entering tannery vats, chemical process towers, nitrogen purged pipe lines, and sewers.

The hazards commonly encountered are:

1. Dangerous vapours, mists, dusts, or fumes.
2. Oxygen lack (which may cause asphyxiation).
3. Ionizing radiation.
4. Fire and explosion.
5. Electric shock.
6. Mechanical hazards, e.g., operation of process equipment while a person is in the enclosure.
7. Extremes of temperature and humidity, or contact with hot objects.

Definite precautions are required for entry into confined spaces, depending on the circumstances. This data sheet outlines the general precautions which should be followed.

Description

A confined space refers to:

1. Completely enclosed structures with limited access, e.g., storage tanks, tank cars, and vessels entered through a manhole.
2. Tanks, pits, vats, vaults, bins, silos, or other structures in which the top is usually open and the structure is sufficiently deep to require special means of entry and provision for emergency exit.
3. Other confined spaces, such as ducts, sewers, tunnels or pipelines.

## Legislation

In Ontario, entry into confined spaces is covered under The Factory, Shop and Office Building Act, R.S.O. 1960, Section 54, Subsection (5), as amended:

"No person shall be allowed to enter a tank, chamber, pit, pipe, flue or other confined space in which dangerous vapours, mists, fumes, dusts or extreme temperatures are liable to be present in a factory unless,

(a) such confined space has a manhole or other means to easy egress and has been thoroughly ventilated and tested to be safe for entry;

(b) such person is wearing suitable breathing apparatus and a safety harness to which there is securely attached a rope the free end of which is held by a person outside the confined space;

(c) there is conveniently available suitable reviving apparatus and a person trained in the operation thereof to the satisfaction of an inspector,

and the safety harness, rope and other apparatus shall be periodically inspected by the employer and maintained in good working order."

## Responsibility

The employer shall take adequate steps to control or eliminate the potential hazards and supervise the work in progress. This also applies to other persons, e.g. contractor's employees.

## Suggested Precautions for Entry into Confined Spaces

1. Education of Workers and Supervisors

   Workers and supervisors shall be informed of:

   (a) the actual or potential hazard to be encountered in entry into any confined spaces within their areas,

   (b) the proper procedures and safety equipment required for entry into such spaces, and

   (c) the proper procedures for emergency rescue work.

Workers and supervisors shall be alerted to any unusual health effect, e.g., headaches, dizziness, irritation, or other ill-effect. They shall be instructed to stop work when they feel their health is being affected, or when unusual operating conditions occur.

2. Ventilation

The confined space shall be well ventilated by mechanical means with clean air where there is liable to be dangerous vapours, mists, fumes, dusts or extreme temperature.

Hot, confined spaces shall be allowed to cool before entry. Inert gas used in purging shall be removed before entry. Ventilation shall be continued while work is being carried out within the enclosure. This serves to provide protection in case of accidental release of chemicals to remove contaminants produced by the work carried out, or to cool the enclosure.
There shall be replacement air for that which is exhausted. To ensure thorough ventilation, the points of air supply and exhaust should be separated as far as possible.
Free oxygen shall not be used to ventilate a confined space.

3. Air Testing

Before entry into confined spaces in which dangerous vapours, mists, fumes, dusts, or extreme temperatures are liable to be present, air testing by a trained person shall be carried out. Direct reading instruments should be used to detect the presence of flammable gases or vapours, or oxygen deficiency. Specific tests for the presence of toxic materials should be made when applicable.

A safe reading with an explosimeter is not, in itself, sufficient to permit safe entry. An atmosphere giving a negative reading on the explosimeter may still be highly hazardous to health.

When the possibility of radioactivity is present, adequate tests by a trained person shall be carried out before entry is permitted.

4. Fire and Explosion

If there is a possibility of fire and explosion, all sources of ignition in the area shall be eliminated. All electrical equipment shall conform to H.E.P.C. requirements for the hazard. Non-ferrous fan blades and non-sparking tools should be used.

Cylinders of oxygen or other gases shall not be taken into confined spaces. This does not apply to breathing equipment. Welding and cutting torches shall not be left in confined spaces when not in use.
Adequate fire fighting equipment shall be readily available.

5. Access and Egress

Confined spaces entered by workmen shall have large enough access to accommodate a worker wearing safety equipment. A manhole should be at least 24" in diameter. Ladders or other suitable means shall be provided where necessary to give ready access and egress. Ladders should be well secured.

Entry shall not be permitted when there is possibility of cave-in of materials.

6. Blanking off

Confined spaces shall be physically disconnected from all lines and systems which may introduce hazard, and these should be blanked off. The blanks should be sufficiently strong to withstand the line pressure and not susceptible to corrosion by materials within the lines.

Experience has shown that valves which are closed may leak; therefore, merely shutting off the valve is not considered adequate.

7. Lock Out of Switches

Electrical switches supplying power to any mechanical apparatus in the confined space shall be tagged and locked in the off position. The worker within the enclosed space should retain the key. In some cases, it may be advisable to pull the line fuses.

8. Electric Shock

Electric tools and equipment should be grounded. Welding electrodes should be well insulated. This is a special problem when welding is carried out inside tanks containing any conductive liquid.

9. Work Permit

A permit in writing from the employer should be obtained before entry is permitted into a confined space. Such permits should specify the conditions for safe entry.

Work permits should be obtained separately for each specific job, location, person and time. Permits should not be carried from one shift to the next. A copy of the permit should be given to the worker in the confined space.

10. Posting of Signs

Special signs to indicate that work is being carried out inside a confined space are helpful. They serve to keep away bystanders, to prevent start-up of dangerous equipment nearby, and to guide rescuers, if necessary.

11. Personal Protective Equipment

Proper personal protective equipment depends upon the nature of the exposure. This may range from chemical goggles, hard hats, gloves, and safety shoes to complete body-covering. If there is liable to be harmful exposure to oxygen lack or to a toxic substance, suitable breathing apparatus shall be provided; canister, cartridge or filter type respirators shall not be used in such cases.

It should be noted that personal protective equipment is not a substitute for proper ventilation.

12. Rescue Equipment

A safety harness with an attached life line shall be worn by persons entering confined spaces where

(a) dangerous vapours, mists, fumes, dusts or extremes of temperature are liable to be present,

(b) respiratory protection is necessary, or

(c) rescue may be difficult.

The free end of the life line attached to the harness should be secured outside the enclosed space. It shall be under the control of a worker stationed outside, who will keep the worker inside under observation at all times. The observer shall be trained in rescue, first aid, and in the administration of artificial resuscitation. For rescue purposes, it is preferable to maintain self-contained breathing apparatus conveniently located outside, together with a safety harness and rope. Suitable reviving apparatus shall be conveniently available at the site.

A portable emergency alarm shall be within reach of the person attending the lifeline.

13. Special Situations

Work in confined spaces may be of a special nature, e.g., relining hot furnaces, maintenance in hot plenum chambers, tank lining work, and cleaning of tetraethyl lead storage tanks. These special situations require detailed additional precautions.

NOTE - This Data Sheet was prepared jointly and has been issued separately as Engineering Data Sheet No. 8-14 and Industrial Hygiene Data Sheet No. 501

References


1. Safety Guide SG-10
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   Entering Tanks and Other Enclosed Spaces.
   Manufacturing Chemists' Association, Inc.,
   Washington, D.C. - 1961.

2. Bulletin No. 312
   Flammable Liquids - Cleaning Small Tanks
   National Board of Fire Underwriters, New York - August, 1962.

3. Bulletin No. 313
   Flammable Liquids - Cleaning Large Storage Tanks that can be Entered.
   National Board of Fire Underwriters, New York - August, 1962.

4. Bulletin No. 314
   Flammable Liquids - Cleaning Tank Cars and Tank Vehicles
   National Board of Fire Underwriters, New York - August, 1962.

5. A.P.I.- Accident Prevention Manual No. 13
   Section A - Tank Vehicles
   Section B - Tank Cars
   American Petroleum Institute, New York.

# EXAMPLES OF WORK IN CONFINED SPACES

| MATERIAL | HEALTH HAZARD | HEALTH PRECAUTIONS | | SAFETY HARNESS AND LIFE LINE | AIR TESTING | VENTILATION | FIRE HAZARD | FIRE PRECAUTIONS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | PROTECTIVE CLOTHING | RESPIRATORY PROTECTION | | | | | | |
| Simple Asphyxiants | | | | | | | | | |
| a. e.g. Nitrogen<br>Black Damp<br>Carbon Dioxide<br>Argon<br>Helium | Yes<br>Asphyxiant<br>Gases | No | Air Supply,<br>Full Face Type | Yes | For oxygen content. Use Explosimeter if gas is used as purge to rid flammables | Purge first, then continuous, adequate ventilation | No | None<br>Where used as purge for flammables, there may be hazard from residual flammables. | Breathing of asphyxiants without oxygen may cause quick collapse. |
| b. Hydrogen | Yes<br>Asphyxiant | No | Air Supply,<br>Full Face Type | Yes | Explosimeter | Purge first, then continuous, adequate ventilation | Yes | Remove sources of ignition. Explosion proof electric equipment and wiring,non-ferrous tools, static grounding. | Breathing of asphyxiants without oxygen may cause quick collapse. Severe fire hazard. |
| Hydrocarbon Gases | | | | | | | | | |
| e.g. Methane<br>Fire Damp<br>Ethane<br>Propane<br>LPG<br>Ethylene | Yes, Act as Asphyxiants and Anaesthetic in High Concentrations | No | Air Supply,<br>Full Face Type | Yes | Explosimeter | Purge first, then continuous, adequate ventilation | Yes | Remove sources of ignition. Explosion proof electric equipment and wiring,non-ferrous tools, static grounding. | Fire Damp, Methane may be encountered in sewers, sewage treatment plants, or where organic material is present. |
| Irritant Gases | | | | | | | | | |
| a. e.g. Chlorine<br>Sulphur Dioxide<br>Hydrochloric Acid Gas | Yes<br>Highly<br>Irritant | Yes,<br>Skin and Eye Covering | Air Supply, Full Face Type.<br>Canister, Cartridge Respirator where concentration below 2% | Yes | For concentration of toxic gas | Purge first, then continuous, adequate ventilation | No | None | Harmful concentrations to health provide adequate warning, due to irritation. |
| b. e.g. Ammonia<br>Formaldehyde | Yes<br>Highly<br>Irritant | Yes,<br>Skin and Eye Covering | Air Supply, Full Face Type.<br>Canister, Cartridge Respirator where concentration below 2% | Yes | Explosimeter and concentration of toxic vapour | Purge first, then continuous, adequate ventilation | Yes | Remove sources of ignition. Explosion proof electric equipment and wiring,non-ferrous tools, static grounding. | Harmful concentrations to health provide adequate warning, due to irritation. |
| Toxic Gases<br>a. Carbon Monoxide | Yes<br>Chemical<br>Asphyxiant | No | Air Supply,<br>Full Face Type | Yes | Concentration of carbon monoxide | Purge first, then continuous, adequate ventilation | Yes | Remove sources of ignition. | Should be suspected where combustion sources located in confined spaces. |
| b. Hydrogen Sulphide | Yes<br>High<br>Hazard | Eye Covering | Air Supply,<br>Full Face Type | Yes | Concentration of hydrogen sulphide | Purge first, then continuous, adequate ventilation | Yes | Remove sources of ignition. | Produced by decomposing organic matter, tannery vats, sewers, septic tanks. |
| c. Cyanides | Yes<br>High<br>Hazard | Skin and Eye Covering | Air Supply,<br>Full Face Type | Yes | Concentration of cyanide | Purge first, then continuous, adequate ventilation | Yes | Remove sources of ignition. | May occur where cyanide salts come in contact with acid. |
| Volatile Solvents & Fuels | | | | | | | | | |
| a. e.g. Gasoline<br>Alcohol<br>Benzol<br>Toluol<br>Xylol<br>Acetone<br>Methyl Ethyl Ketone | Yes | Skin and Eye Covering in High Concentrations | Air Supply,<br>Full Face Type | Yes | Explosimeter and concentration of toxic vapour | Purge first, then continuous, adequate ventilation | Yes | Remove sources of ignition. Explosion proof electric equipment and wiring,non-ferrous tools, static grounding. | Type of purge depends on specific material. Health effects vary, depending on material, e.g. benzol on chronic exposure, is particularly toxic, affecting blood organs. |
| b. e.g. Carbon Tetrachloride<br>Trichlorethylene<br>Perchlorethylene | Yes | Skin and Eye Covering in High Concentrations | Air Supply,<br>Full Face Type | Yes | Concentration of toxic vapour | Purge first, then continuous, adequate ventilation | Usually<br>No | Trichlorethylene is flammable in high concentrations. | Trichlorethylene vapours commonly encountered in cleaning degreasing pits. |
| Inert Dusts<br>Cement<br>Limestone | No<br>(Cement Dust is an irritant in high concentrations) | Eye Protection may be needed | Filter Type<br>Face Mask | Yes, if entry from top of tank or silo | No | Natural | No | None | |
| Combustible Dusts<br>Grain<br>Coal | Some persons are allergic to Grain Dust | No | Filter Type<br>Face Mask<br>may be needed | Yes, if entry from top of tank or silo | No | Natural | Yes | Explosion proof electrical equipment and wiring,non-ferrous tools. | Combustible dusts may explode violently under certain conditions. |

# WELL REHABILITATION

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## INTRODUCTION

A well requires maintenance during it's life, to keep it performing at the design capacity. Depending upon the location, design and operation of the well, the screen area will gradually plug, due to mechanical, chemical, or bacterial effects. The following will outline the causes of plugging the means of determining if the well is plugging, and the steps that should be taken to correct it.

## WELL HYDRAULICS

To understand what takes place in the well as it plugs, it is useful to review the hydraulics of a well.

First of all, we can picture the aquifer as a permeable formation, capable of storing and transmitting water. It can be composed of sand and gravel, or it can be a consolidated formation, such as limestone or sandstone. To produce water from an aquifer, we construct a well. When the well is not producing, the distance from ground level to the water level is referred to as the static level.

After a well starts to pump, the water level drops to the pumping level, and the amount it drops is called the drawdown. Part of the drawdown is due to the resistance to the flow of water in the aquifer itself. The second portion is related to the well only, and is dependent upon the well design and construction techniques. This second portion of the drawdown, which is due to the well itself, is known as the well loss, and is referred to in feet of drawdown at a particular capacity.

Some well loss will be present in a new well, although it may be too small to measure practically. It is caused by plugging of the formation by drill cuttings and drilling mud, or incomplete removal of fines from around the screen during development. The well will gradually plug with pumpage, and well losses will increase. This is caused by migration of fines from the formation, precipitation of chemical encrustments, or growth of nuisance bacteria in the vicinity of the well screen.

## DETERMINING WELL LOSSES

The amount of well loss in a new well should always be established as a basis for future comparison. There are two methods of determining well losses in a new well, or in an operating well. The first method, which is preferable, makes use of a drawdown-distance test. This involves pumping the well at a constant capacity and observing the drawdown in the well, and in one or two nearby observation wells.

The second method is a multiple step-test. The well is pumped at two or more different capacities, and the drawdown is recorded at each capacity. This method is not as accurate as the drawdown-distance method, but the observation wells are not required.

A further check on well performance can be made by maintaining a regular record of pump capacity and pumping level. Not only is it sound operating procedure, but you can establish whether drawdown is increasing, and if so, conduct a test to confirm if it is due to increased well losses.

## PLUGGING PROCESS

We probably have a poorer knowledge of the cause of plugging than any other process connected with groundwater development. To begin with, although we recognize the plugging can be mechanical, chemical or bacterial, in practice it is often a combination of two or more of these factors.

Mechanical plugging is due to the presence of fines from the native formation, or from drill cuttings jamming the flow area of screen and surrounding formation. It can be caused by over pumping a well, surging of a well by stop-starting, reverse flows from the system, or the continued effects of incomplete development.

Chemical plugging results from a chemical encrustment forming on the screen and around the screen. Not certain is the cause of this deposition. One explanation is that $CO_2$ in the groundwater maintains a certain concentration of dissolved minerals in solution. As the groundwater approaches the screen, the pressure drops, releasing the $CO_2$. This, in turn, upsets the chemical equilibrium and causes the minerals to precipitate.

An alternative explanation is that the chemical deposition is a result of an electrical chemical process, set up when two dissimilar metals, such as the well screen and the well casing form electrodes, and are immersed in an electrolyte groundwater, to form an electrical cell. Then, as in any electrical cell, minerals are deposited in the vicinity of one of the electrodes, in this case, in the area of the well screen.

PLUGGING PROCESS - Cont'd

The minerals deposited can eventually bind the sand and gravel into a solid encrustment.

The origin of bacterial plugging is also difficult to explain. It could be introduced from the surface, either during construction, or by leakage down the well from the system. Groundwater is also known to contain bacteria that has existed in the aquifer for centuries. When a well goes into production, favourable conditions for it's rapid expansion may result in the area of the well screen. This can cause the formation of a chemically encrusted bacterial growth, which will not only plug the well, but will produce bad taste and odour in the water.

METHODS OF WELL REHABILITATION

Having established that the well is plugging, and then determining the probable cause, there are various techniques available to restore the well capacity. They fall into two classifications, mechanical, and chemical. The objective of mechanical rehabilitation is to create pressure waves or surges in the formation outside the screen. This can be done by stop-starting the pump, backwashing from a riser pipe or the system, mechanical or air agitation, and high pressure jetting. Fines plugging the formation are loosened by the mechanical surging and are drawn through the screen, where they can be removed. Some wells respond satisfactorily to mechanical methods, but the surging effect is so quickly dampened out in the formation it is difficult to remove material more than a few inches from the screen face. If the well is a double cased design, the ability to reach out from the screen can be improved by running wash lines between the casings outside the screen.

The use of explosives could also be considered as a form of mechanical agitation. This method has few applications, and in general, is mishandled. The objective in using explosives in a screened well is to set up small but high frequency vibrations in the screen area. The vibration will fracture any rigid chemical encrustments that are present, providing more contact area to react to subsequent chemical treatments. Explosives in cased wells should be used with extreme caution, as the large casing diameters are subjected to high rupturing forces. Since the well may have been in service for several years before rehabilitation, corrosion will have weakened the screen and casings, making them more vulnerable to the forces developed by explosives.

METHODS OF WELL REHABILITATION - cont'd

Explosives can also be used in certain types of sandstone wells, creating vibrations to remove a thin skin from the face of the bore hole. Only a small charge is required, and the improvement will be just as great as that produced by a larger charge, with far less debris to remove. Too large a cavity will also hamper future efforts to rehabilitate the well.

Chemical treatments are effective in removing the mud cake left during mud-rotary drilling, in dissolving chemical encrustments, and in removing bacterial growths. Although difficult to maintain the required concentration and proper distribution along the screen area, due to variation in specific gravities and dilution by the formation water, when properly applied, the use of chemicals can be more effective than mechanical methods in reaching out from the screen.

Drilling mud and some types of soft iron deposits can be removed, using a polyphosphate treatment. However, it can cause secondary problems by making silt or clay deposits overlying the aquifer unstable, and considerable difficulty may be experienced in cleaning up the well. Since polyphosphates can accelerate growth of bacteria, a high concentration of chlorine must always be maintained in the well during treatment.

Acidizing is most effective in removing iron carbonate encrustments, or in dissolving iron deposits created by iron reducing bacteria. The reaction of the acid with the plugging agent or formation will often be violent, and extreme caution is required during treatment, to avoid personal injury or damage to equipment. Certain types of rock wells are very receptive to acidizing, which not only removes any chemical encrustment, but may free drill cuttings that are jammed into the bore hole face during drilling.

Bacterial plugging is treated with a chlorine solution. Chlorine concentration will range from 50 to 500 ppm, depending on the type of bacteria present. This is often followed by an acid treatment, to dissolve the chemical deposit that has collected on the bacteria. Following any type of chemical treatment, some form of mechanical agitation should be carried out, to remove any of the fines or cuttings that are freed when the chemical binder is dissolved.

RECONSTRUCTION

In some cases, the well screen and surrounding formation becomes so badly plugged that mechanical and chemical rehabilitation are unsuccessful in restoring well capacity. When economically justified, the screen can be removed and the well re-drilled. A new screen and gravel wall is placed, followed by a normal well development program.

## FACTORS CONTROLLING PLUGGING

There are several important factors that will affect well plugging:

(a) The well should be designed, using the best materials and design that are available. There is often a desire to reduce diameters, or accept a minimum design for initial economy. This will not only accelerate plugging, but will hamper efforts to rehabilitate the well properly.

(b) The method of well construction, with particular emphasis on development, is a major factor in well plugging. A well that requires considerable development during construction in order to stabilize the fines is generally more sensitive to plugging than a well that develops quickly. We also encounter some wells that have higher specific capacities after rehabilitation, because they were incompletely developed during construction. Had these wells been properly developed, plugging would have been considerably reduced.

(c) Rehabilitation of a well before plugging is too well established will ensure greater success. When plugging is too far advanced, and the formation is solidly encrusted, no form of chemical or mechanical treatment can be effective.

(d) The proper type and application of rehabilitation methods is important. Rehabilitation programs require substantial time, material, and know-how to complete successfully. Half-hearted attempts, or short cuts, will only produce short term improvements, or no improvement at all.

Operation of a well field requires constant monitoring of well performance. As soon as there is any indication from the production records that plugging is taking place, a proper test should be conducted, to confirm it. If action is taken immediately, the well performance can be restored and the useful life of the well will be extended. Well rehabilitation is not successful in every instance, and results can vary from well to well, or the same well may respond to the same treatment that was used successfully on an earlier occasion. To produce the maximum amount of water from a well during it's life, it is essential that plugging be controlled by regular rehabilitation.

# DEEP WELL PUMPS

## SOME THEORY, TESTING AND MAINTENANCE COMMENTS

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The two most common types of deep well pumps being used today are the <u>deep well turbine pump</u> and the <u>submersible turbine pump</u> and these are the types of pumps we shall be discussing. Pumps such as deep well reciprocating, air lift, etc. are not within the scope of this paper.

### SOME PUMP TERMS

#### Turbine Pump

The turbine pump is a multi-stage centrifugal pump, i.e., a pump having more than one impeller (stage) (See Figs. 1 & 2)

#### Submersible Turbine Pump

The submersible turbine pump is a turbine pump, with the drive motor submersible in the well water (See Fig.3)

#### Drawdown

Drawdown is the distance that the water is lowered by pumping. It is the actual distance in feet between the static water level and the pumping (or dynamic) level. (See Fig. 4 - depth A)

#### Static Water Level

Static water level is the level to which water rises when the well is not being pumped. It is generally the level of the water table except in the case of artesian wells where the static water level may be above the water table. The static water level is measured from approximately the ground surface to where the water rises when there is no pumping (See Fig. 4 - depth B).

Pumping Level

Pumping level is the level at which water stands in the well when pumping at a given rate. This level is variable and changes with quantity pumped. In tests this level must be checked several times and calculations of capacity should not be made until several readings have been taken at least one hour apart. One can then be sure that the well has reached an equilibrium at the quantity pumped. (See Fig. 4 - depths A & B)

Pump Submergence

Pump submergence is the distance from the pumping level to the top of the pump. Proper submergence is important for reliability of operation, (See Fig. 4-depth C)

Capacity

Capacity is the amount pumped in gallons per minute, per hour, etc. An Imperial Gallon (about 277 cubic inches of volume) is larger than a U. S. Gallon (231 cubic inches.) Imperial Gallons = U. S. Gallons x 0.833.

Static Head (water to water)

Static head is a difference in elevation. A pumping system's total static head is the total height from minimum water level in the well to the maximum elevation of the water in the water tank to which the the pump delivers (See Fig. 5A), or the maximum elevation of the discharge end of the pipe line depending on whichever is greater. (See Fig.5B)

Friction Head

Friction head is the head of water pumped necessary to overcome friction losses caused by the water flowing through piping and fittings (in both suction and discharge). Friction head varies with volume of flow and size, type and condition of pipe.

Velocity Head

Velocity head is the kinetic (or dynamic, or moving) head of the water. In addition to having to supply power to the water to lift it against its static head and to overcome pipeline friction additional power or energy must be supplied to keep the water moving at the required velocity.

Velocity Head (continued..............)

The friction losses in the <u>suction line</u> of a deep well pump are usually charged to the pump itself and therefore the total head on a deep well pump is:

<u>Total Head</u>

Total head is the sum of the static head + the discharge friction losses.

Please note that it is extremely important that you tell the pump supplier what heads you have included in the total head calculation and if at all possible you should send him a copy of your calculations complete with sketch.

## SOME BASIC THEORY

Pumping is the addition of energy to a fluid - in our case, to water. Energy is the ability to do work, and therefore we can cause the water to do work, such as flow through a pipe or rise to a higher level, by adding energy.

Energy may exist in two forms, viz.: potential energy, which is energy of position, and kinetic energy, which is energy of motion.

In a centrifugal pump a motor (or other driver) rotates an impeller in an enclosed casing. This rotation creates a flow from the centre of the impeller to its rim and the mechanical energy put into the impeller by the drive is changed primarily to kinetic energy, in the movement of the water outward through the impeller.

A major part of this kinetic or velocity energy is not usable as such because the high velocity of the water would give excessive friction losses and therefore it is necessary to transform most of this velocity energy into potential energy to overcome the pumping. There must of course be some kinetic energy to create flow. The hydraulic function of the discharge bowls of a deep well turbine pump or submersible turbine pump is therefore to provide a flow passage of gradually increasing area so that velocity energy is changed to potential energy.

SOME BASIC THEORY (continued.....)

The head developed by a pump is determined by the impeller diameter and its speed. With deep well turbine and submersible turbine pumps, the maximum impeller diameter is determined by the diameter of the bowl, which in turn is restricted by the well diameter. Since well diameters are usually small the head developed by a single impeller is not great and it is usually necessary to use more than one impeller to create the required pumping head, hence the term turbine pump. The head produced by such a pump is directly proportional to the number of impellers, i.e. for a given capacity a two stage pump will produce twice the head of a single stage pump and so on.

Capacity is determined by the area through which flow occurs and by the velocity of flow. Velocity is dependent upon the peripheral speed of the impeller so that quantity is determined by the width of the impeller with constant speed. Of two impellers of the same diameter running at the same speed, the one having the greater width will deliver the greater capacity.

It is known that:-
Keeping impeller diameter and width constant:

$$\frac{RPM_1}{RPM_2} = \frac{CAP_1}{CAP_2} = \frac{\sqrt{H_1}}{\sqrt{H_2}} = \frac{\sqrt[3]{HP_1}}{\sqrt[3]{HP_2}}$$

and, keeping the speed and width constant

$$\frac{DIA_1}{DIA_2} = \frac{CAP_1}{CAP_2} = \frac{\sqrt{H_1}}{\sqrt{H_2}} = \frac{\sqrt[3]{HP_1}}{\sqrt[3]{HP_2}}$$

In other words if the speed is for example, doubled, the capacity will be doubled, the head will be x4 and the horsepower required will be x8, or if, for example, the diameter of the impeller is halfed the capacity will be halfed, the head will be x $\frac{1}{4}$ and the H.P. required will be x 1/8.

Example 1: It is required to increase the capacity of a 600 USGPM, 220 Ft. head, 60 HP, 1800 RPM, impeller $\phi$ = 9" pump from 600 USGPM to 660 USGPM, what will the required new speed, the increase in head and the increase in horsepower required at the pump shaft.

$$\frac{CAP_1}{CAP_2} = \frac{RPM_1}{RPM_2}, \quad \frac{600}{660} = \frac{1800}{RPM_2}, \quad RPM_2 = \frac{1800 \times 660}{600} = 1980 \text{ RPM}$$

$$\frac{CAP_1}{CAP_2} = \frac{\sqrt{H_1}}{\sqrt{H_2}}, \quad \frac{10}{11} = \frac{\sqrt{220}}{\sqrt{H_2}}, \quad \frac{100}{121} = \frac{220}{H_2}, \quad H_2 = \frac{220 \times 121}{100} = 266.2 \text{ Ft.}$$

$$\frac{CAP_1}{CAP_2} = \frac{\sqrt[3]{HP_1}}{\sqrt[3]{HP_2}}, \quad \frac{10}{11} = \frac{\sqrt[3]{60}}{\sqrt[3]{HP_2}}, \quad \frac{1000}{1331} = \frac{60}{HP_3}, \quad HP_3 = \frac{60 \times 1331}{1000} = 79.86 \text{ HP}$$

Example 2. Same problem as above but what would new required diameter be if it was decided to hold the speed constant.

$$\frac{DIA_1}{DIA_2} = \frac{CAP_1}{CAP_2}, \quad \frac{9}{DIA_2} = \frac{600}{660}, \quad DIA_2 = \frac{9 \times 660}{600} = 9.9"$$

It should be remembered, however, that as any changes are made in capacity, impeller diameter, speed or head, then the efficiency of the unit must be checked to ensure that it is economical. It is always best to consult the supplier of the pump before you make any changes. He will normally give advice as a free service.

MEASURING LEVEL

When a turbine pump is installed in a well a highly desirable accessory is a water level measuring device. One can be made quite easily from a Bourdon tube type pressure gauge (preferably graduated in feet), an air hand or foot pump, a Shrader type air valve with 1/8" male thread, $\frac{1}{4}$ x $\frac{1}{4}$ x 1/8 tee and sufficient $\frac{1}{4}$ tubing with couplings and elbows to extend down into the well to the bottom of the pump. See Figure 6.

At the time of installation of the air pipe in the well an accurate measurement and record should be made of the exact number of feet of pipe put into the well. This recorded length is the basis on which all water - level data is calculated.

To check the static water level pump air into the air pipe (keeping pump off) until the indicator on the air gauge ceases to register increasing pressure. At this point sufficient air has been pumped to expel completely all water in the air pipe, and air pressure will exactly equalize the column of water in the well above the bottom of the air pipe. The air gauge reading then gives the head of water above the bottom of the air pipe. Subtract this gauge reading from the reading of the recorded air pipe length and the remainder is the distance down to the static water level.

If S = water level below pump base in feet
L = recorded air pipe length below pump base in feet
G = gauge reading in feet
P = gauge reading in psi, then,

$$S = L - G$$

or, $$S = L - (P \times 2.31)$$

with reference datum being pump base.

To determine the pumping or dynamic water level the above procedure is repeated with the pump running and drawdown is: pumping level - static level.

## MEASURING CAPACITY

There are a number of ways to measure capacity, some of which are outlined below.

### a) Weight and Volume Method

This is the most accurate method with weight and volume being measured in a container, but the measurements must be carefully done. Whilst ideal in the laboratory it is not suitable for normal field tests because to obtain accurate results the equipment required is too large and expensive. We can, of course, use a barrel but if in a test a 50 gallon barrel is filled in 10 seconds and we assume that we are pumping 300GPM $(50 \times \frac{60}{10})$ we will probably have an error of about $\pm$ 10% or greater.

### b) Weir Method

In the weir method an obstruction is placed across a channel and the head of water above the obstruction (weir) is measured. From this the capacity is calculated. Whilst the measurements are easy to make, care must be exercised in the building and installing of the weir to obtain accurate results. There are a number of different types of weir, some of which are shown in Figures 7,8 &9. Note that all have obstructions and end contractions which can be placed across a well constructed ditch.

The rectangular weir is easy to construct but has the disadvantage of requiring the use of a complicated formula. The trapezoidal weir is more difficult to construct since its side slope must be exact, but calculation data is made easier by a little simpler formula. For small flows the triangular weir gives more accurate results than other weirs.

The construction of the weir and of its channel of approach and the setting of the weir in the channel all affect the accuracy obtained. The channel of approach should be straight for some distance above the weir, the weir face must be vertical and the weir crest must be level. Head measurement is extremely important and must be made accurately with a float gauge or such (although a rule can be used) it should be taken 3 times the head of water upstream from the weir.

Accuracy of pump tests using a weir is again probably no better than $\pm$ 10% error because of inaccuracies in field construction.

c) Orifice Meter Method

This is a common method and is perhaps the most accurate for field work. It requires the use of a special orifice plate which can be inserted into the pipe line and across which the pressure drop can be measured. The gallonage is then read off a graph against pressure drop. It may also be installed at the end of a discharge pipe with open discharge to atmosphere. Accuracy is about $\pm$ 5%.

d) Rule Method

This requires the use of an L-shaped rule with the shorter side being 4" long, the longer any convenient length. With the water flowing from the horizontal open discharge, place the long side of the L-rule along the top of the discharge pipe, allowing the shorter side to hang down as shown in Figure 10. Slide L-rule along the pipe until 4" length barely touches the flow of water. Note the distance 'X' travelled by the water before it drops 4" and determine the flow rate from the table in Figure 10.

This method is very easy to use and gives an indication of the flow with an accuracy of about $\pm$ 10%.

For the effort involved in taking the reading this gives good results.

At best all field tests are no better than $\pm$ 5-10% accuracy which means that for a 300 GPM test the actual flow may be 285 GPM or less, on 315 GPM or more.

MEASURING POWER

On pumps driven by electric motors the power input is obtained by using a wattmeter. If a wattmeter is not available, a reasonably accurate result can be obtained by timing the revolutions of the disc of the standard electric meter, the watt-hour meter. Each of these meters has a disc constant applying to that particular meter, stamped either on the meter case or on the disc itself. Using this constant, the horsepower input to the motor is found by the formula:

$$\text{Input HP} = \frac{4.83 \times K_h \times R}{T}$$

where, $K_h$ = watt-hour meter disc constant
$R$ = number of revolutions of disc
$T$ = time in seconds for R

A stop watch should be used and at least 10 revolutions of the disc must be timed.

## SUBMERSIBLE MOTORS

A number of these have been developed but we shall only mention two. The oil-filled motor has windings treated with an oil resistant varnish and the motor is filled with insulating oil. The success or failure of the oil filled motor depends on the sealing mechanism. Although shaft seals have been improved over the years, no rotating seal is perfect and it is only a matter of time until the seal leaks. The oil filled motor is relatively inexpensive and this is the only reason why it is still being offered today. OWRC does not encourage this type of submersible motor.

The better type of submersible motor is of the water-filled type. In this type of motor, the winding wire is covered with a waterproof, non-aging insulation. Water is not kept out of the motor, instead the motor is filled with water before it is installed. Water is used to cool the windings, and to lubricate the motor bearings, the water providing constant, consistant lubrication at no cost that cannot break down.

These motors need no regular maintenance and probably the most common fault is grounding of one of the phases on the electrical supply either at the junction entry into the motor or due to cable breakdown over a long period of time.

Overload relays with standard trip-heaters designed for air cooled motors do not provide protection for submersible motors. Quick-trip relay heaters are required for protection of submersible motors. It is not advisable to use the heater selection tables found in control manufacturer's catalogues since these are intended for air cooled motors; it is best to contact the motor supplier.

## SOME MAINTENANCE POINTS

A loss or reduction in delivered capacity may be due to one or more causes. Some can be determined without disturbing the pump while others can be checked only by pulling the unit for examination.

Troubles that can be checked without disturbing the pump are:

a) Reduction in motor speed (low voltage or frequency)
b) Leak in discharge piping
c) Capacity or pressure measuring device out of calibration.
d) Increase in operating head or pressure on discharge side of pump.
e) Drop in static ground-water level.

Pump troubles that can be checked only by actual examination are:

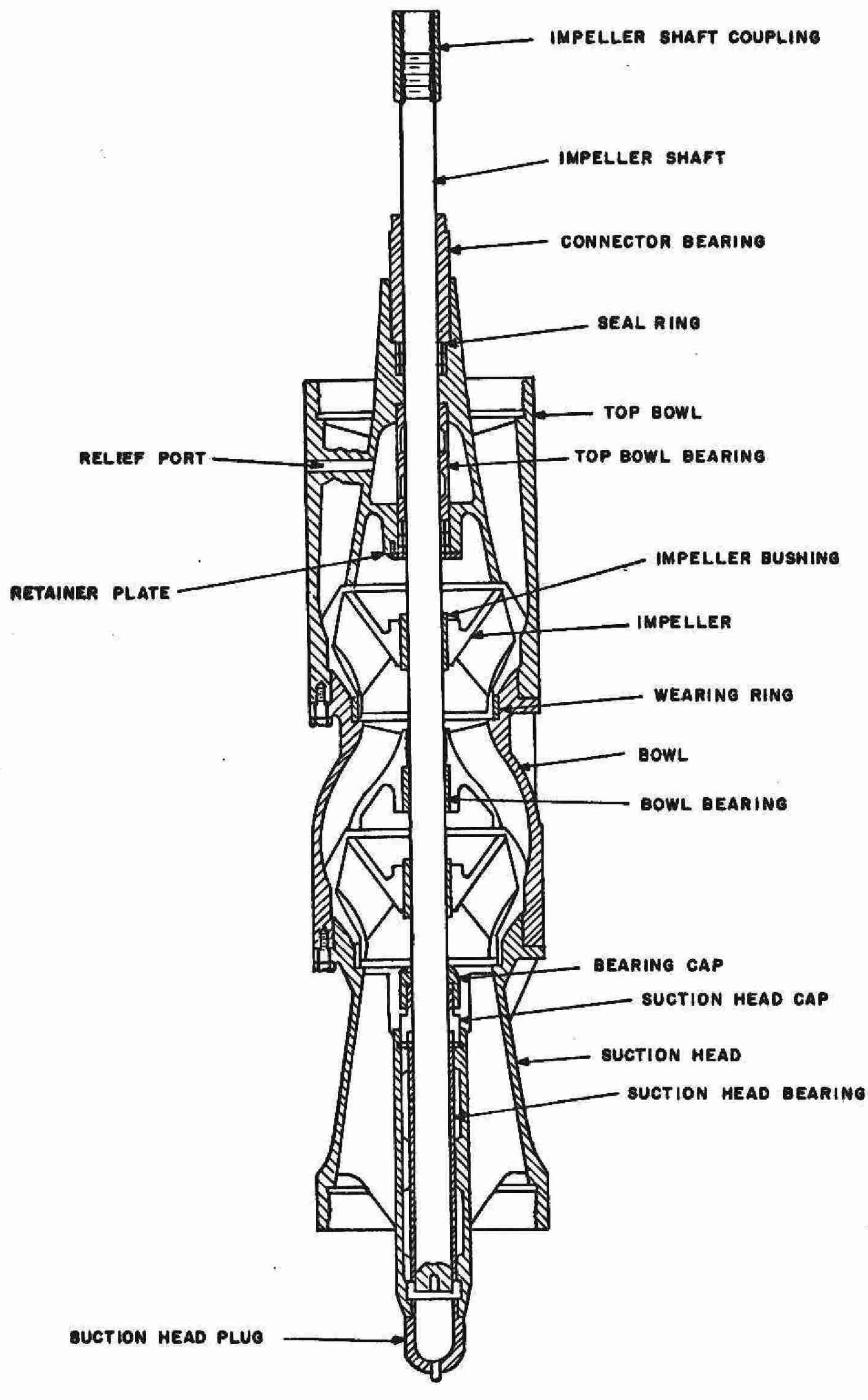
a) Partial plugging of impeller section or strainer.
b) Loose impeller or impellers on shaft.
c) Leak in column piping.
d) Worn impeller skirts or stationary wearing rings.

If it is necessary to check the static water level the pump should be shut down for about 15 minutes before checking the level to allow the well and water-bearing strata conditions to stabilize.

We have tried to give a somewhat overall glance at deep well pumps and we have not been able to concentrate on any one part. However, should you wish any further or deeper explanations or if you have any problems you wish advice on please give me a call and we will do our best to assist you.

FIG. - I

SECTION OF BOWL OF VERTICAL TURBINE PUMP
(CLOSED IMPELLERS)

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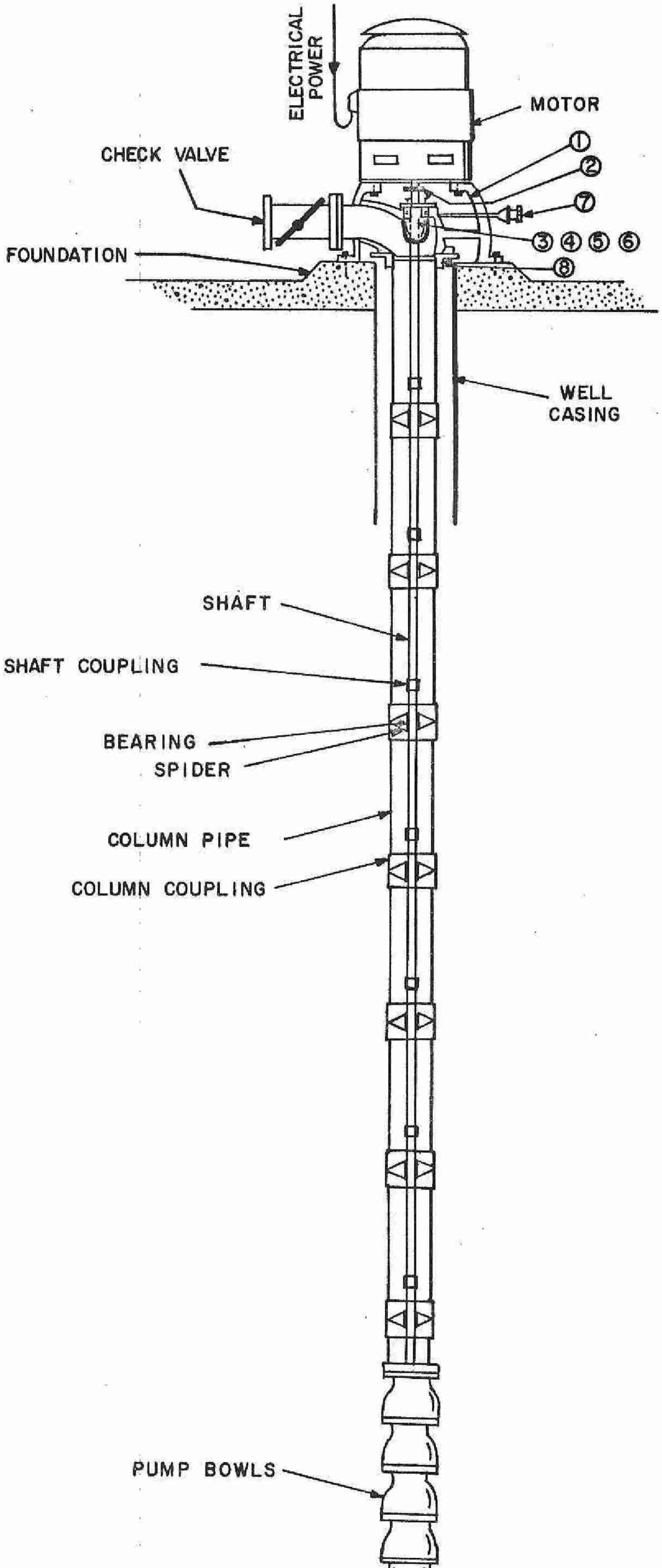
L.L.8

FIG-2

VERTICAL TURBINE PUMP




1 - DISCHARGE HEAD
2 - DEFLECTOR
3 - PACKING BOX
4 - PACKING GLAND
5 - PACKING
6 - P.B. BUSHING
7 - P.B. GREASE LINE
8 - COLUMN FLANGE

NOTE

Shaft Coupling, Bearing, Spider & Column Coupling Every 10 FEET

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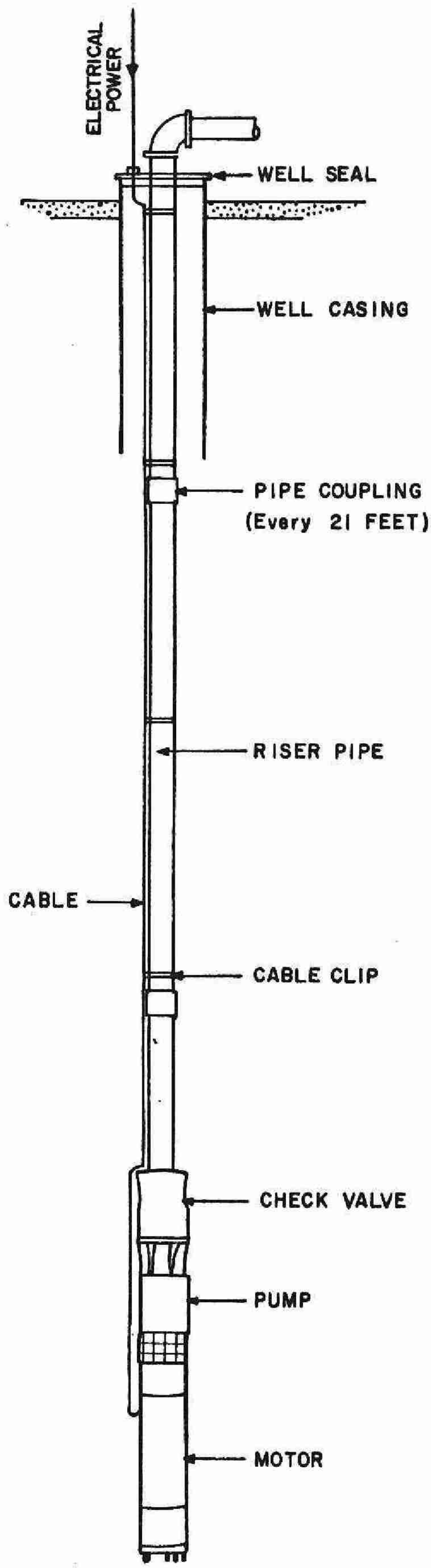
L.L.B.

FIG - 3
SUBMERSIBLE TURBINE PUMP

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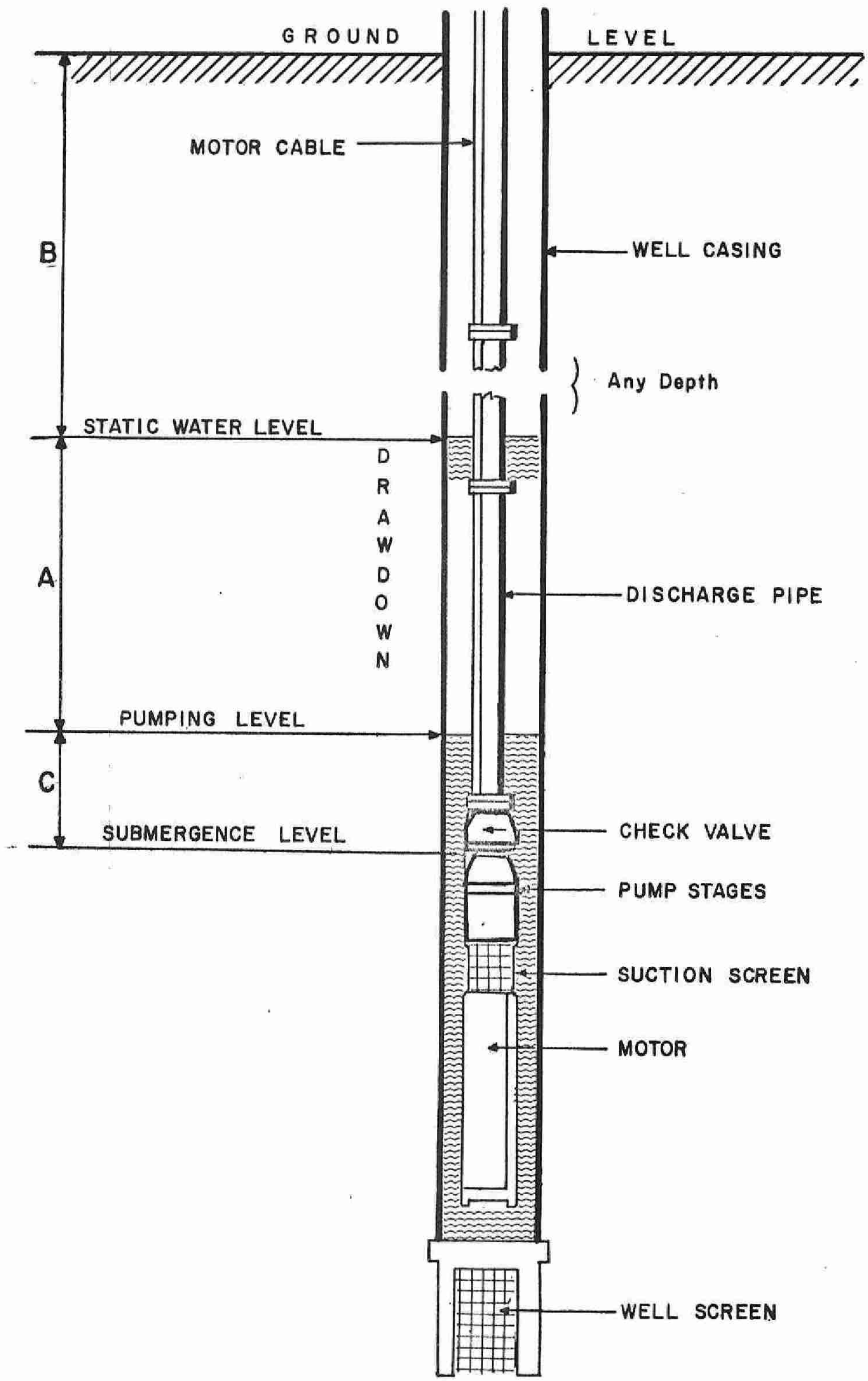
L.L.B.

FIG.—4

ILLUSTRATION OF WATER LEVELS

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L.L.B.

FIG. - 5A
STATIC HEAD

FIG. - 5B
STATIC HEAD

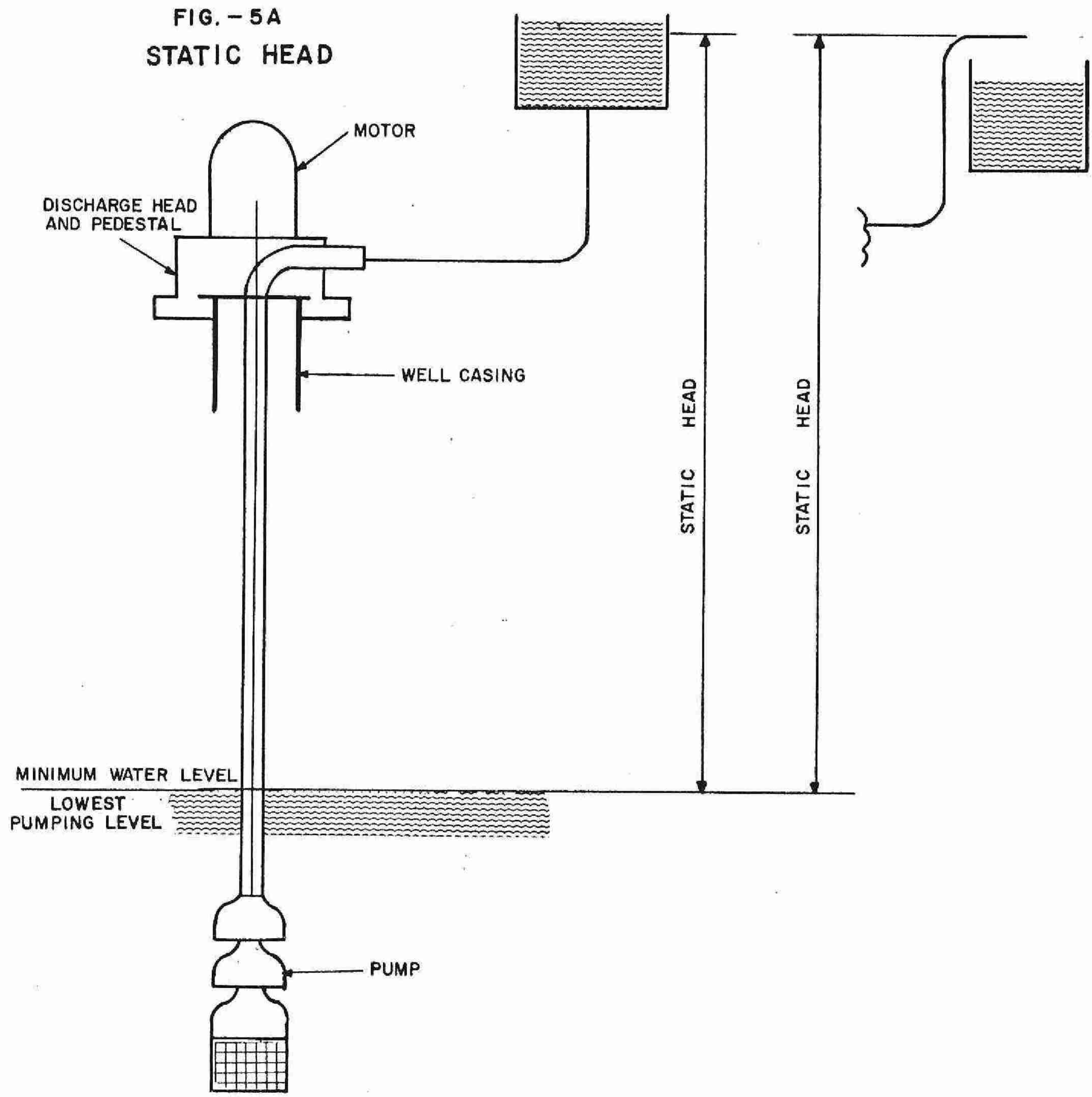


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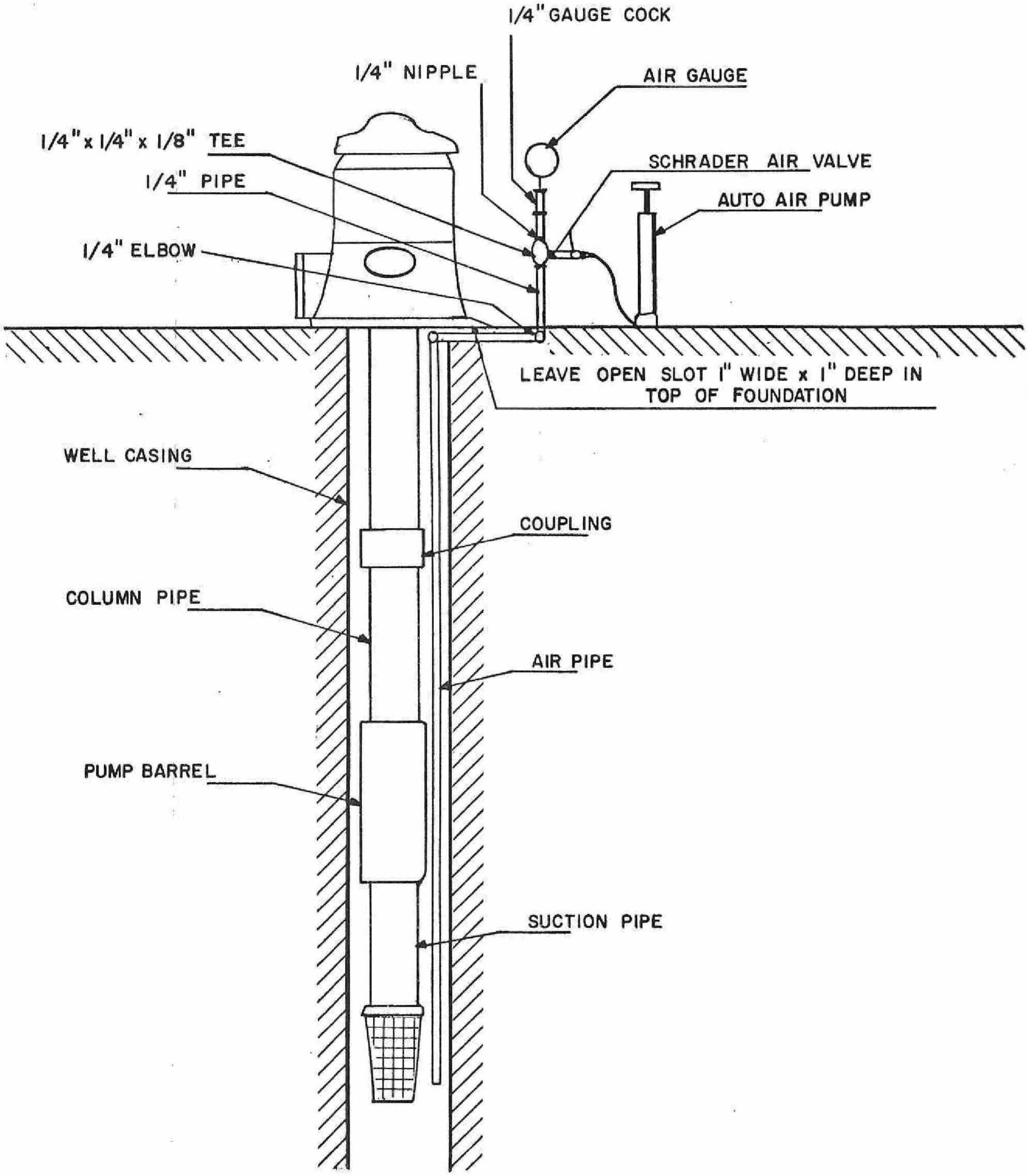
FIG. – 6
EASILY MADE DEVICE FOR MEASURING WATER LEVEL

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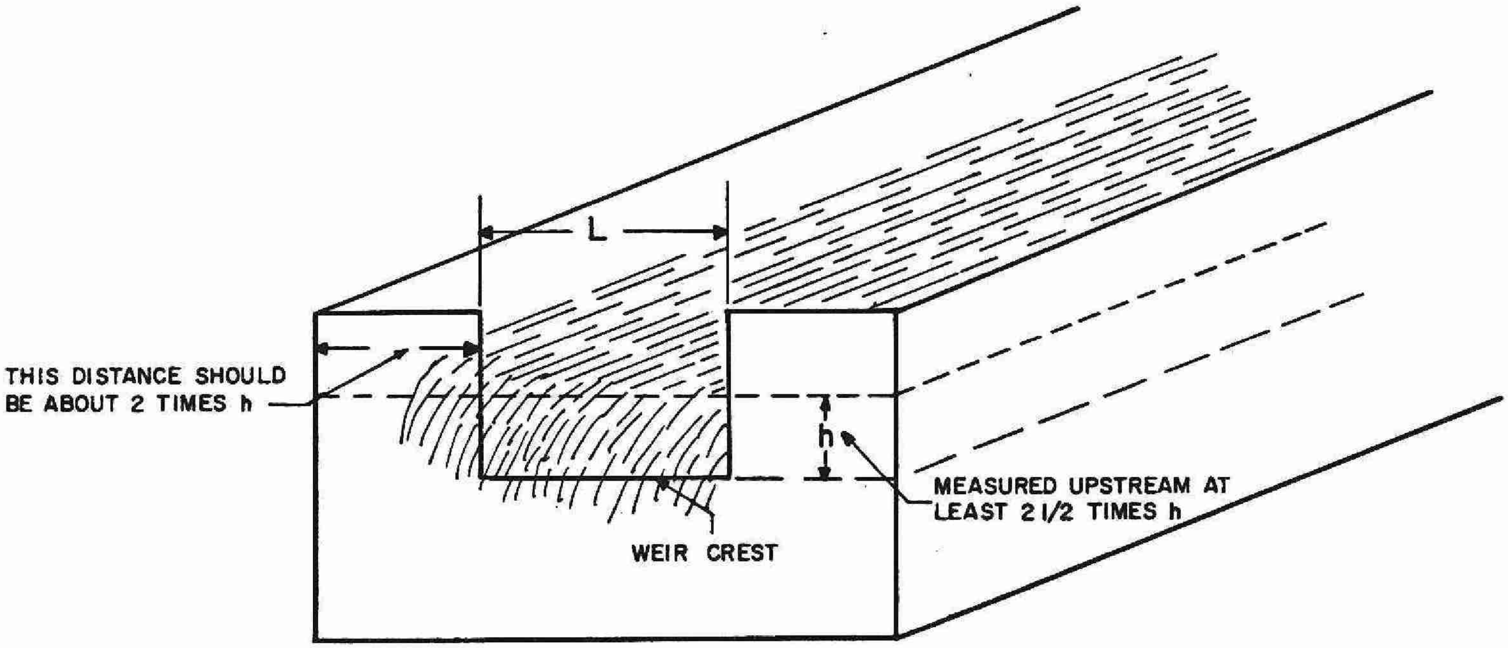
L.L.B.

FIG.-7
RECTANGULAR WEIR




$$Q \text{ (in Cu. Ft./Sec.)} = 3 \cdot 33 \, (L - 0 \cdot 2\, h)\, h^{\frac{3}{2}}$$

$$Q \text{ (in GPM)} = 1495 \, (L - 0 \cdot 2\, h)\, h^{\frac{3}{2}}$$

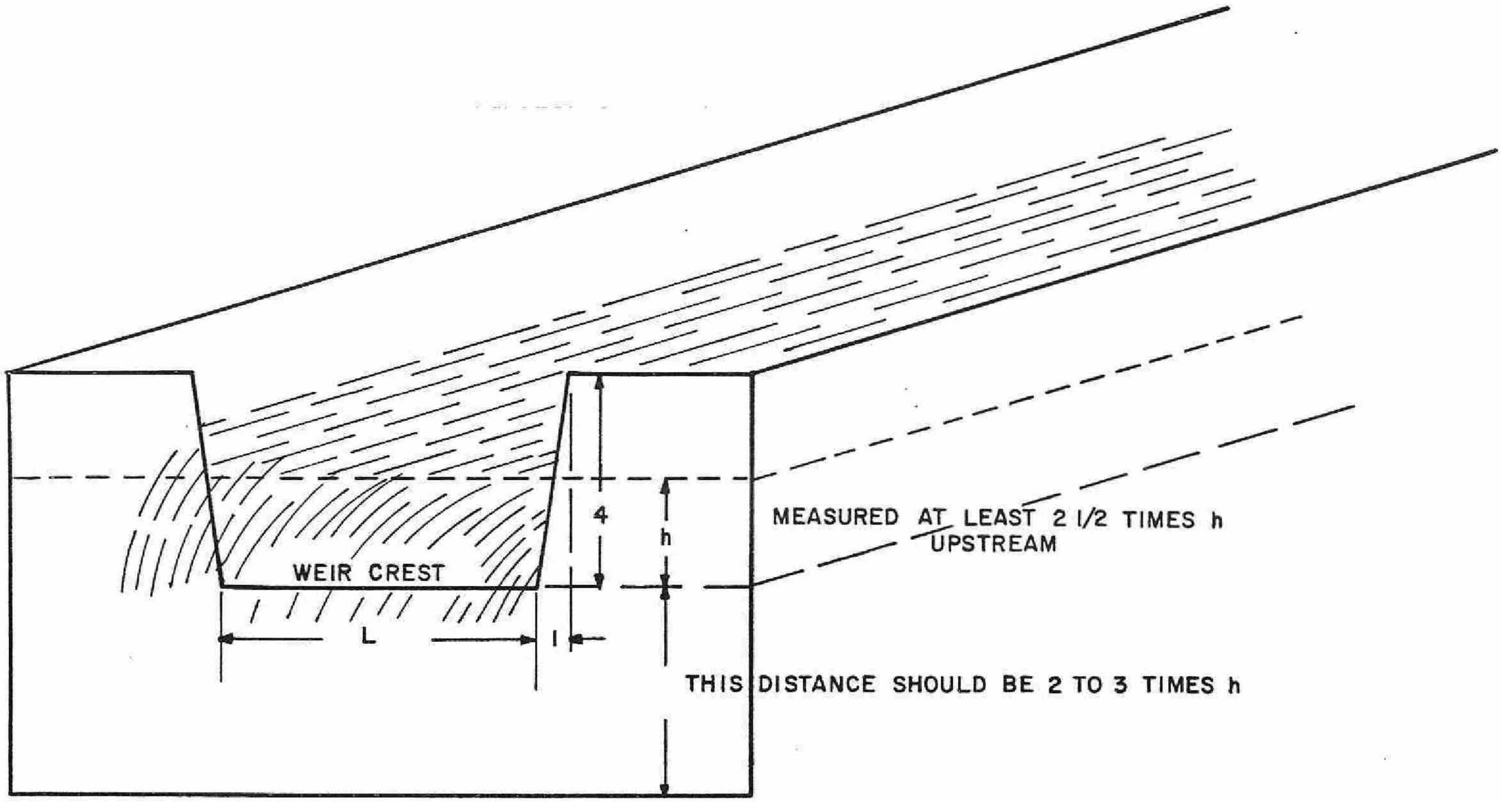
L and h MEASURED IN FEET

E - 17

DWG. No : 69-183 - PO
L.L.B.

FIG. - 8

## TRAPEZOIDAL OR CIPPOLLETTI WEIR




CREST LENGTH "L" SHOULD BE AT LEAST 2 TIMES h

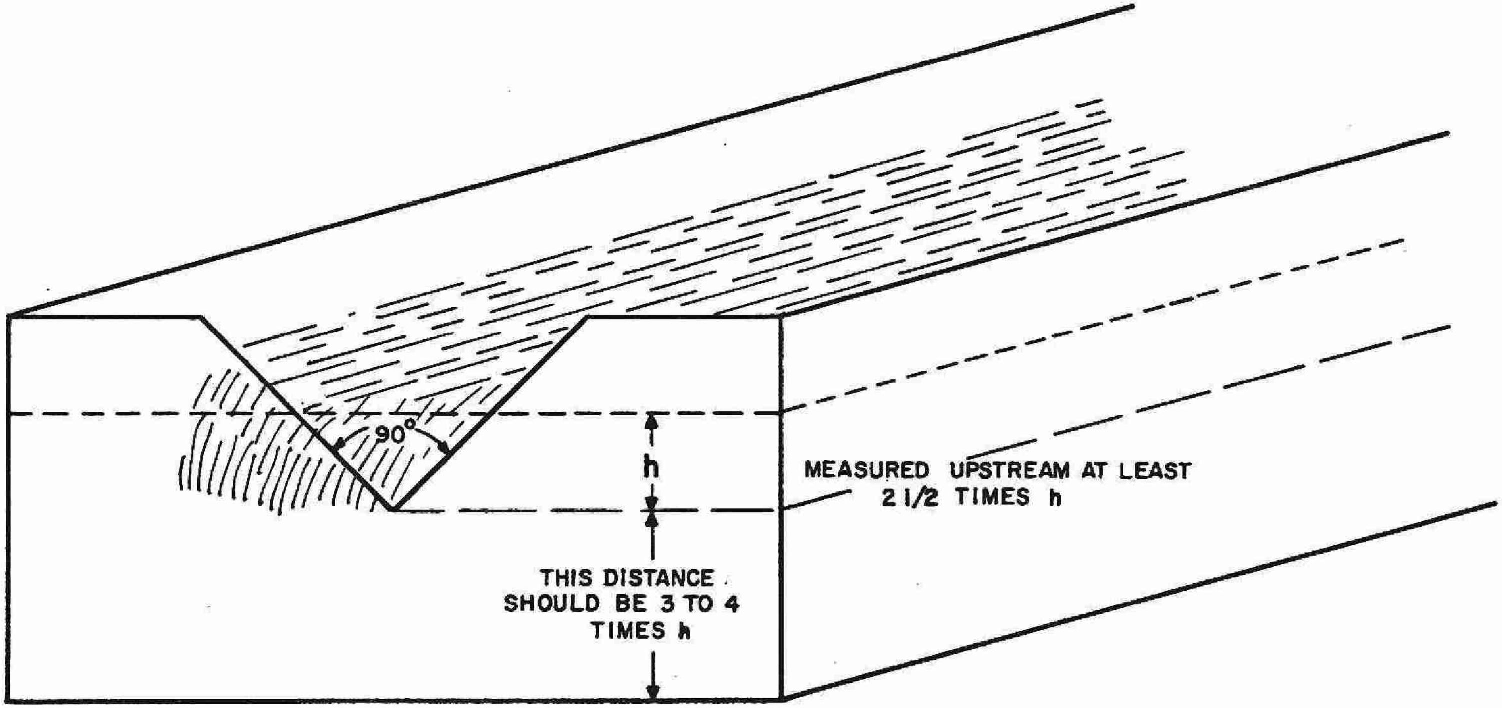
$$Q \text{ (in Cu. Ft/Sec.)} = 3.33\ L\ h^{\frac{3}{2}}$$

$$Q \text{ (in GPM)} = 1495\ h^{\frac{3}{2}}$$

L And h MEASURED IN FEET

DWG. No: 69-184-PO
L.L.B.

FIG.—9
TRIANGULAR WEIR




WITH 90° NOTCH ANGLE AS SHOWN, THE FORMULA FOR CAPACITY IS SIMPLIFIED AND BECOMES

$$Q \text{ (in Cu. Ft./Sec.)} = 2.54\, h^{\frac{5}{2}}$$

$$Q \text{ (in GPM)} = 1140\, h^{\frac{5}{2}}$$

h MEASURED IN FEET

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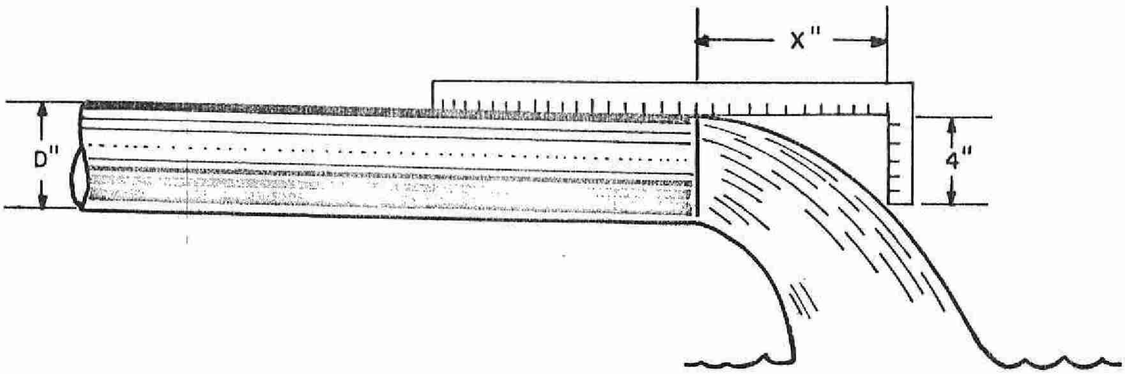
L.L.B.

# FIG. - 10
## PUMP DISCHARGE RATE OF FLOW




### DISCHARGE RATE US GPM

| Horiz. Dist. X (Inches) | Nominal Pipe Diameter 1" | 1 1/4" | 1 1/2" | 2" | 2 1/2" | 3" | 4" | 5" | 6" | 8" | 10" | 12" | Average Velocity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 5·7 | 9·8 | 13·3 | 22·0 | 31·3 | 48·5 | 83·5 | | | | | | 2·1 |
| 5 | 7·1 | 12·2 | 16·6 | 27·5 | 39·0 | 61·0 | 104 | 163 | | | | | 2·6 |
| 6 | 8·5 | 14·7 | 20·0 | 33·0 | 47·0 | 73·0 | 125 | 195 | 285 | | | | 3·1 |
| 7 | 10·0 | 17·1 | 23·2 | 38·5 | 55·0 | 85·0 | 146 | 228 | 334 | 580 | | | 3·7 |
| 8 | 11·3 | 19·6 | 26·5 | 44·0 | 62·5 | 97·5 | 166 | 260 | 380 | 665 | 1060 | | 4·2 |
| 9 | 12·8 | 22·0 | 29·8 | 49·5 | 70·0 | 110 | 187 | 293 | 430 | 750 | 1190 | 1660 | 4·7 |
| 10 | 14·2 | 24·5 | 33·2 | 55·5 | 78·2 | 122 | 208 | 326 | 476 | 830 | 1330 | 1850 | 5·3 |
| 11 | 15·6 | 27·0 | 36·5 | 60·5 | 86·0 | 134 | 229 | 360 | 525 | 915 | 1460 | 2200 | 5·8 |
| 12 | 17·0 | 29·0 | 40·0 | 66·0 | 94·0 | 146 | 250 | 390 | 570 | 1000 | 1600 | 2220 | 6·2 |
| 13 | 18·5 | 31·5 | 43·0 | 71·5 | 102 | 158 | 270 | 425 | 620 | 1080 | 1730 | 2400 | 6·9 |
| 14 | 20·0 | 34·0 | 46·5 | 77·0 | 109 | 170 | 292 | 456 | 670 | 1160 | 1860 | 2590 | 7·4 |
| 15 | 21·3 | 36·3 | 50·0 | 82·5 | 117 | 183 | 312 | 490 | 710 | 1250 | 2000 | 2780 | 7·9 |
| 16 | 22·7 | 39·0 | 53·0 | 88·0 | 125 | 196 | 334 | 520 | 760 | 1330 | 2120 | 2960 | 8·4 |
| 17 | | 41·5 | 56·5 | 93·0 | 133 | 207 | 355 | 550 | 810 | 1410 | 2260 | 3140 | 9·1 |
| 18 | | | 60·0 | 99·0 | 144 | 220 | 375 | 590 | 860 | 1500 | 2390 | 3330 | 9·7 |
| 19 | | | | 110 | 148 | 232 | 395 | 620 | 910 | 1580 | 2520 | 3500 | 10·4 |
| 20 | | | | | 156 | 244 | 415 | 650 | 950 | 1660 | 2660 | 3700 | 10·6 |
| 21 | | | | | | 256 | 435 | 685 | 1000 | 1750 | 2800 | | 11·4 |
| 22 | | | | | | | 460 | 720 | 1050 | 1830 | 2920 | | 11·8 |
| 23 | | | | | | | | 750 | 1100 | 1910 | 3060 | | 12·4 |
| 24 | | | | | | | | | 1140 | 2000 | 3200 | | 13·0 |

For other than standard diameter pipes the flow may be determined by using the following formula:

$Q$ gpm = $X \cdot 1{\cdot}28D^2$ where D = Inside pipe diameter

X = Horizontal open flow for drop of 4"

DWG. No: 69-185-PO
L.L.B.

# OPERATION AND MAINTENANCE OF CONTROL AND METERING EQUIPMENT

Spencer Grey

Instrumentation Specialist
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Today instrumentation is somewhat of a confusing word, depending on a person's acceptance of its meaning. It is sometimes associated with automation, but I like to think of instrumentation as a system of control which can measure a process and control some or all parts of it.

Quite often we mention instruments, which is a particular unit, when what we are actually referring to is instrumentation. We are all familiar with our automatic appliances, such as toasters, clock radios, stoves, furnaces etc. These all have forms of instrumentation inasmuch as they have an automatic control of some process, such as toasting bread, turning on the radio, baking, heating our houses, etc., so it is not such an imposing word after all.

When used in the industrial field, it does measure and/or control a process. Now a process is any operation from pumping water to providing treatment or manufacture of a substance. In the waterworks field, instrumentation will measure the flow of water, control the pressure, pH, chlorine residual, etc., level of reservoirs and, in so doing, will automatically control pumping, filter backwashing, chlorine dosage, alum dosage, etc.

## Why is Instrumentation Necessary?

Over the years, the physical sciences have been used to augment our sense of temperature, viscosity, pressure and colour. We are incapable of sensing, within narrow limits, differences in temperature, speed, colour, or light intensity. Therefore, we have produced mechanical aids that never get tired, seldom go on strike, and that not only are extremely accurate and sensitive in their response, but keep those characteristics for extended periods of time.

As individuals, we cannot maintain maximum efficiency for more than a very short time. If our senses were sufficiently accurate, which they are not, more than three people, per 24-hour day, would be required to monitor each station or group of stations, that one person could sense and keep under control on any one shift.

Here we are concerned with that instrumentation which will help us improve and maintain the quality of water which we are supplying to the water system. In the very simplest system we are merely pumping from a well or other sources of water to a reservoir or tower, while in the more complex systems we will pump from an intake, through a filtering or treatment system, to another pumping station and into a final system or reservoir.

As with most things we do, we want to know what we are getting and the cost of the operation. To do this we must naturally know the flow or quantity of water supplied, and if treatment is required, to automatically control the quality.

The first thing to do is to measure the flow by means of a flow meter operated mechanically, or by differential pressure types. The mechanical type we are all familiar with, since probably we all have one in the basement of our houses, on which we are billed for our consumption of water. The differential pressure types, which we deal with here, allow us to control our system more easily and we will examine several methods of how this is done.

Pressure is force per unit area, e.g. pound per square inch or pound per square foot. A common way of measuring this is by use of a manometer which balances a column of liquid in static equilibrium. If we take a piece of glass tubing and bend it to form a 'U' and fill it partially with a liquid, we then have a very simple form of manometer. It is one of the most accurate ways of measuring relative pressure.

With a simple bent tube filled with some liquid such as water or mercury and open at both ends to atmosphere, we note that the liquid will balance so that both levels are equal above a reference line. (Diagram 1A).

Anywhere in the tube we have an equal pressure point to another at the same level from the reference line. It does not matter that one side of the tube is larger than the other as both are subject to the same pressure. All points at equal distance from the reference line in the liquid are subject to the same pressure (Diagram B).

When we introduce an external pressure to one leg, the other remaining with the same pressure, we find that the liquid in one leg will go down while the other goes up. If we take a point pa in the short leg and point pb in the long leg that are equal levels above the reference line and point pc to represent the distance from pa/pb to the level of the short leg, we find that equal pressure is represented on pa by p external plus pc, and on pb by pl plus pc-pi being the pressure of the higher column of liquid, The distance between the lower and higher points of the liquid, hi measured and applied to the specific gravity of the liquid will tell us the pressure applied in respect to atmospheric pressure. If we apply two pressures the distance hi will tell us the differential pressure on the system.

Differential pressure types of instruments use a change of pressure to determine velocity and hence flow. The principle used here is that a flow of liquid through a constriction in a pressure conduit results in a lowering of pressure at the constriction. This pressure change is proportional to or reflects the velocity of the fluid flowing through the restriction.

The device used to first provide this differential pressure is known as a Primary Device, and the most common forms are:

Orifice Plates
Venturi Tubes
Dall Tubes
Pitot Tube
Flow Nozzle
Elbow Meter

All of these devices use a change in pressure and operate either a manometer type of instrument or a differential pressure transmitter.

The differential pressure method of measuring flow is probably the most common. However, flow measurements can be made in open channels by the use of a Parshall flume or the use of a weir plate. With a Parshall flume it is common to use a stilling well and float which in turn will indicate the level of flow through the flume. To measure the flow over a weir, a bubbler tube can be used and with a fixed discharge of air, the head pressure on the bubbler tube will be an indication of the flow.

By the use of suitable levers, gears, etc., this change of pressure or level can be indicated as a flow value, it can also record or transmit the information to another point where it can indicate, indicate/record, indicate/record/control, functions such as pumps.

The primary device, along with a transducer which is merely a means of changing one type of signal to another with an indicator, is known as a transmitter. That unit which receives this signal and either indicates, records, or indicates and records, is known as a receiver. These units may be in the same box cabinet or they may be separated by a few feet or a few miles. When the information is transmitted to another location it is known as telemetering.

The transducer along with the associated units are known as secondary devices. These secondary units are divided into three groups, namely:

Mechanical
Pneumatic
Electrical which includes electronics

The mechanical type of instruments are operated by rods, gears, linkages and cables connected to the pressure take off on the primary devices. This, of course, eliminates lengthy piping arrangements which must be leak-free. Mechanical units usually allow much flexibility in that portions of the unit can be removed and replaced without disrupting the flow of the material being measured. Disadvantages are in the lag of the instrument due to inertia and friction of the mechanical parts, slippage in the linkage wear and breakdown of the moving parts and it does require considerable lubrication.

The pneumatic type of instruments, while using mechanical linkages and parts for indication, are using a varying controlled-air pressure ranging from 3 to 15 p.s.i. This signal can be transmitted by piping over distances up to 1500 feet to operate the required instrument. The advantages of this system is that the installation and maintenance costs are low while a continuous signal output with an extensive sensitivity to change in the variable being measured is provided. The main disadvantage is the relative short distance the signal can be transmitted and that a clean dry air supply is required.

Electrical types of instruments will naturally use some mechanical linkages for indication, but the signal is an electrical current or voltage change. This can be transmitted over great distances between the transmitter and receiver, with little loss of signal strength or a time lag that is apparent in other systems. The cost of this type of system is usually a little higher, but recent advances are causing it to be used more frequently in the smaller systems of control with a consequent decrease in cost.

To return now to the pneumatic type of instruments, you will note that there are two illustrations of differential pressure transmitters. In the Bourdon tube type the signal pressure is applied to the element, and it is the twisting effect of the Bourdon tube which is used to provide an indication or to do some other work.

With the bellows type of differential pressure transmitter use is made of a force beam. This beam is set on a pivot and at one end two bellows are placed for the two pressures of the signal, and at the other end there is a balancing bellows with a 'flapper' nozzle, air supply and indicating gauge. With a change in the pressure at the low side, there is a corresponding change in the position of the beam. The changing position of the beam opens or closes the orifice through which a constant air supply is flowing. The balancing bellows provides a constant pressure to the force beam according to the position of the beam in relation to the orifice. This reflected pressure is used to give an indication of the pressure applied to the force beam and is in turn a direct relation to a flow measurement.

The indication of flow as provided by the d/p transmitter can be used to operate an electrical type of signal transmission. One type of electrical instrument uses a revolving cam across which an arm rides and it is the length of time which the arm is on or off the cam which gives the pulse duration of the electrical signal. This signal at the receiver operates a magnetic clutch arrangement, which will move the indicator up or down according to the change of pulse duration.

Another type of electrical instrument uses a variation in current caused by a change in a magnetic field, or a change in position of a potentiometer. When the position of the iron core is changed in the magnetic field the flux density is changed causing a change in the current flowing in the external circuit. This also applies to the change of the position of the arm of the potentiometer, which will change the current flow in that leg of the bridge circuit.

The electrical instruments are becoming smaller due to the use of transistors and also are becoming cheaper by the more prevalent use of this type of unit.

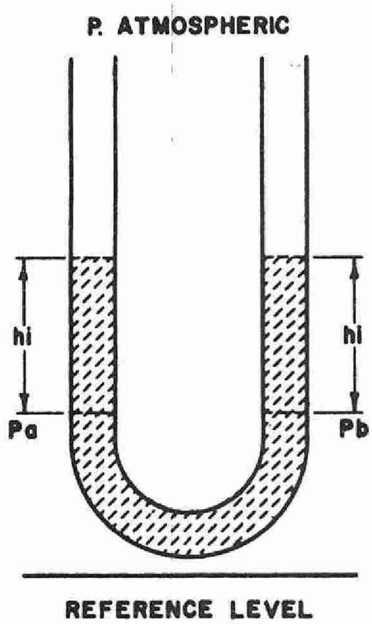
While we have covered a brief outline of instrumentation in regards to flow measurements, we must not forget the other measurements and controls that are necessary. As mentioned earlier, it may also be necessary to control the addition of chemicals to the water or to control a filtering process. The control of chemicals to the water may be done by continuous sampling or measuring for chlorine content, pH, or other required information, and these measurements, through an instrument controller, will maintain a set value or dosage.

The number of pumps required to maintain a certain level of water in a reservoir or tower can be controlled by the rate of flow as indicated by any one of the flow indicators, by means of suitable control circuits. The automatic backwash of a filter can be done by the measurement of the pressure across the filter bed, and at a predetermined value will automatically shutoff the flow of water through the filters and proceed with the backwash operation.

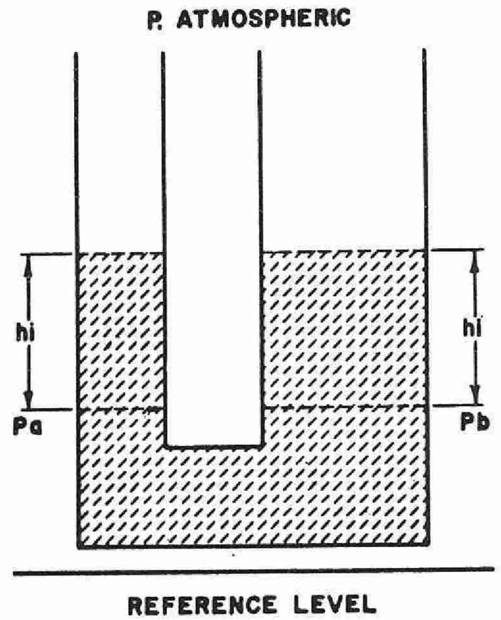
Instrumentation does require a trained technician to maintain the instruments in calibration and repair. However, the principles of operation are simple and can be understood by the operator. This understanding will assist in determining the limitations of the equipment and what may be done in a particular problem. It must be remembered that all flow instruments are only accurate to 1% in the 20 to 80% range, 5% in the 10 to 20% and 80% to 90% range, and cannot be considered accurate below 10% scale.

It is not our intention to continue the 'little black box' theory in regards to instrumentation, but to help disperse the mystery to allow the operation of the instruments to be of some importance to the operator.

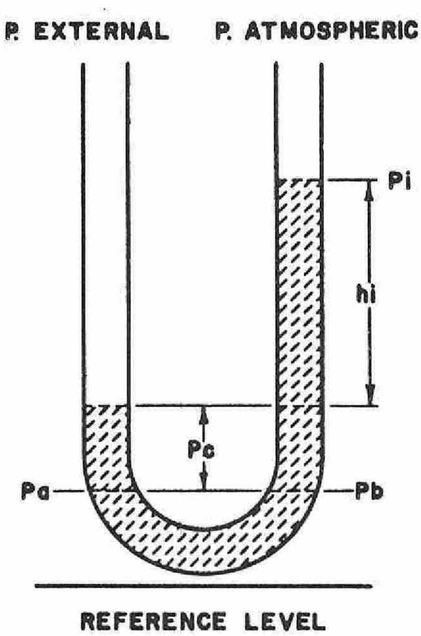
## DIAGRAM - I




A




B



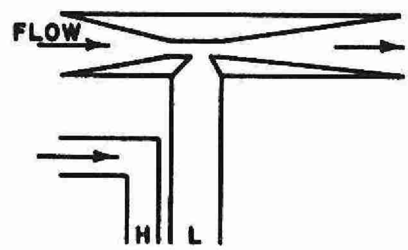

C

## U-TUBE MANOMETER

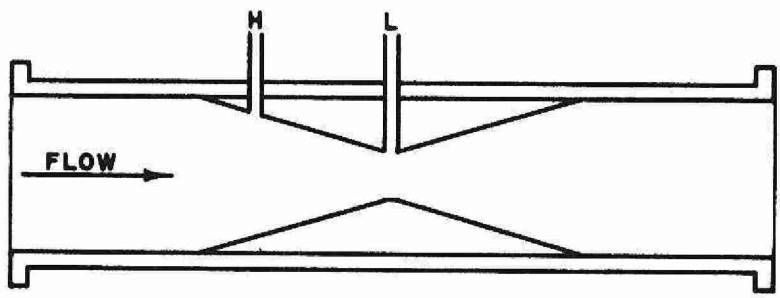
A — PRESSURE BALANCE ANY SET OF POINTS OF EQUAL HEIGHTS ABOVE REFERENCE.

B — PRESSURE EQUALITY OF POINTS AT SAME HEIGHT ABOVE REFERENCE INDEPENDENT OF SIZE OR SHAPE OF LEGS.

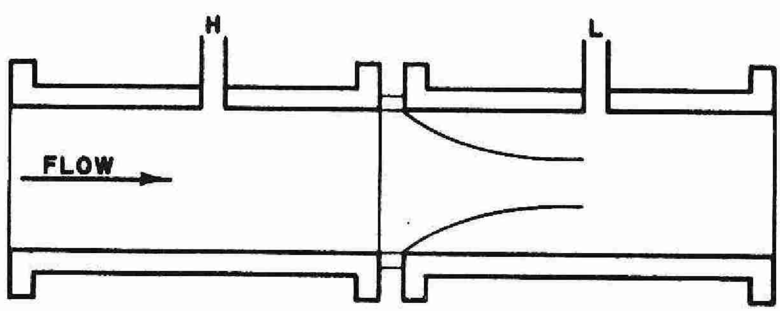
C — PRESSURE DIFFERENTIAL SHOWS LIQUID RISES IN LEG SUBJECTED TO SMALLER PRESSURE.



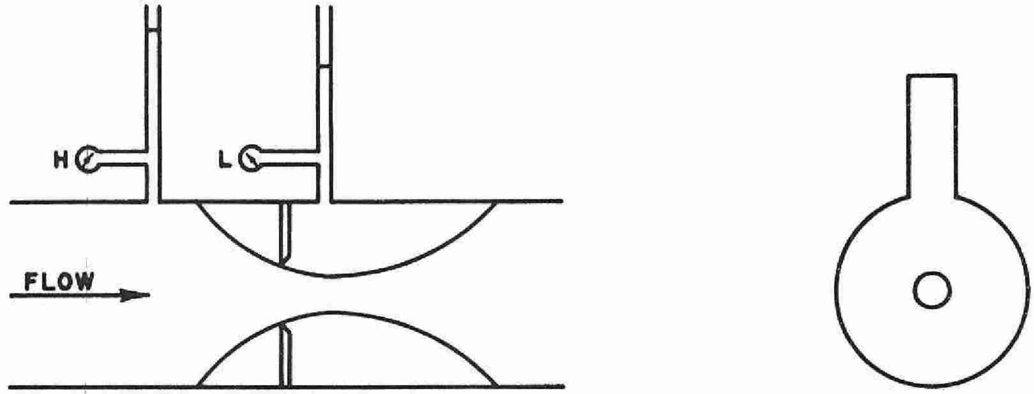

PITOT TUBE



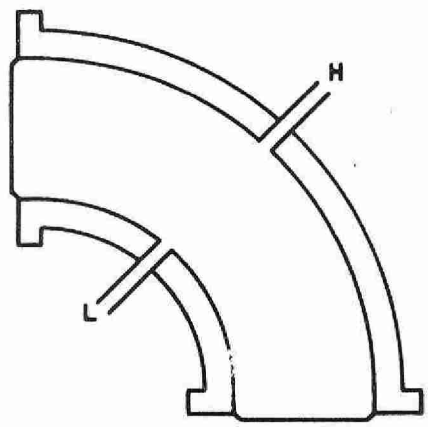

DALL TUBE



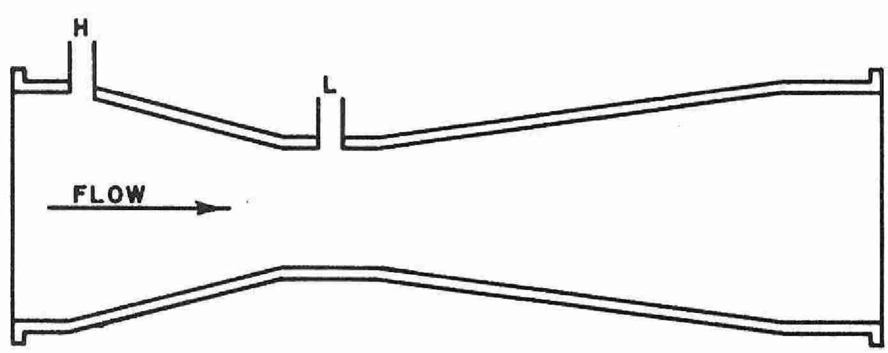

FLOW NOZZLE




ORIFICE PLATE

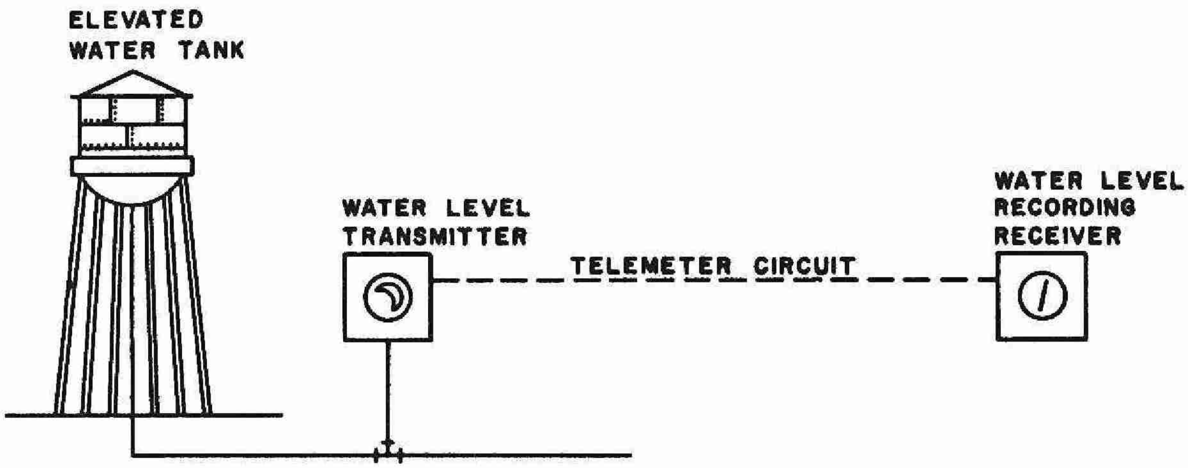



ELBOW METER

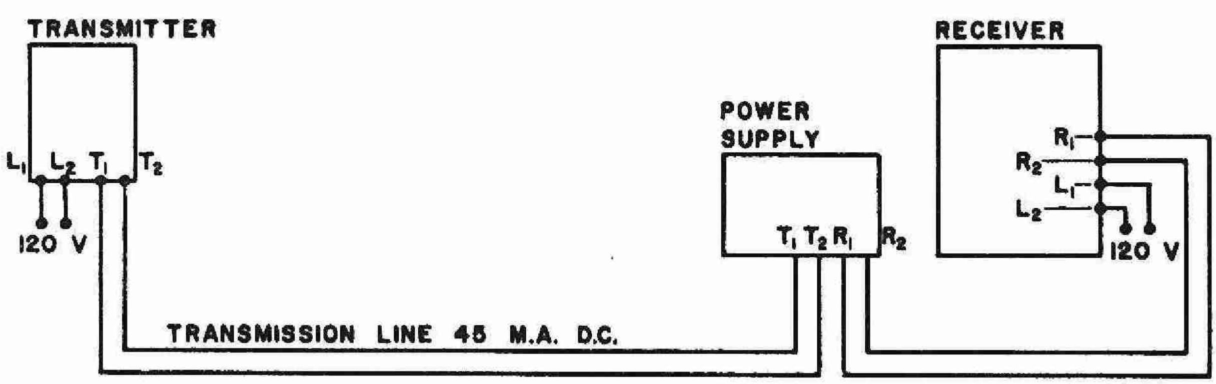



VENTURI TUBE

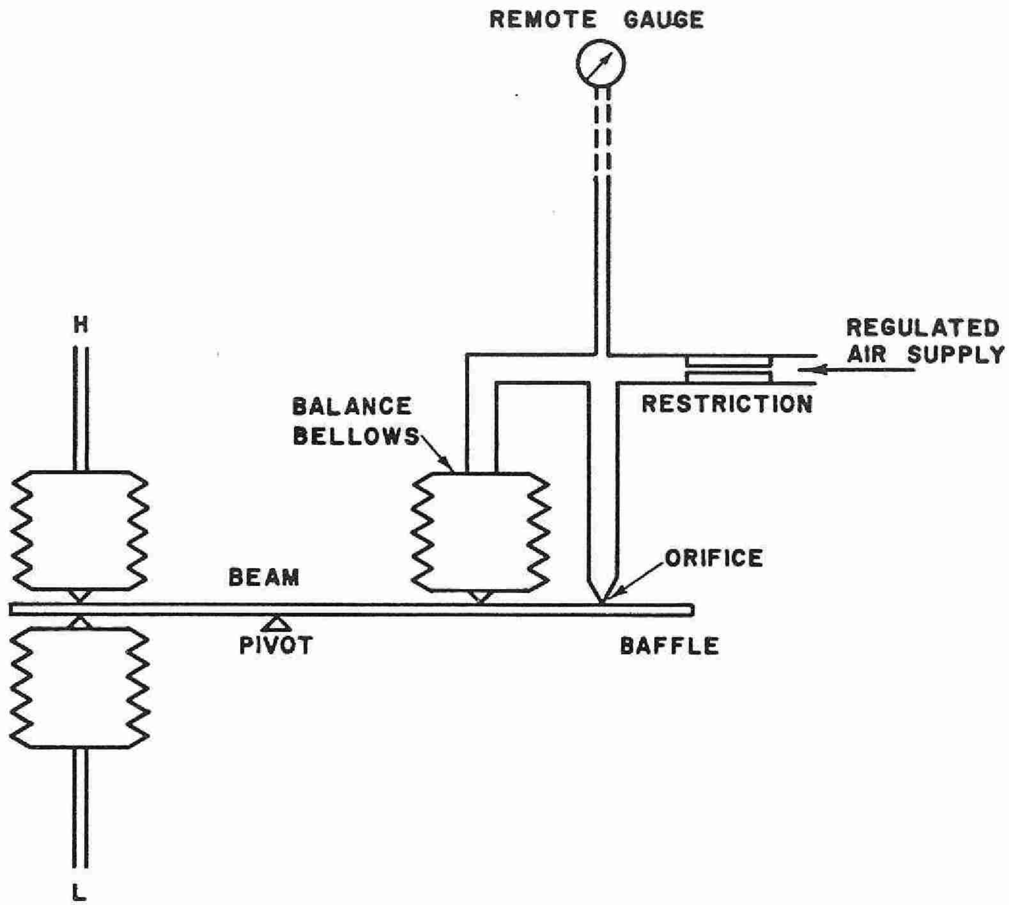
## REMOTE MEASUREMENT OF LEVEL IN WATER TOWER USING ELECTRIC TELEMETER



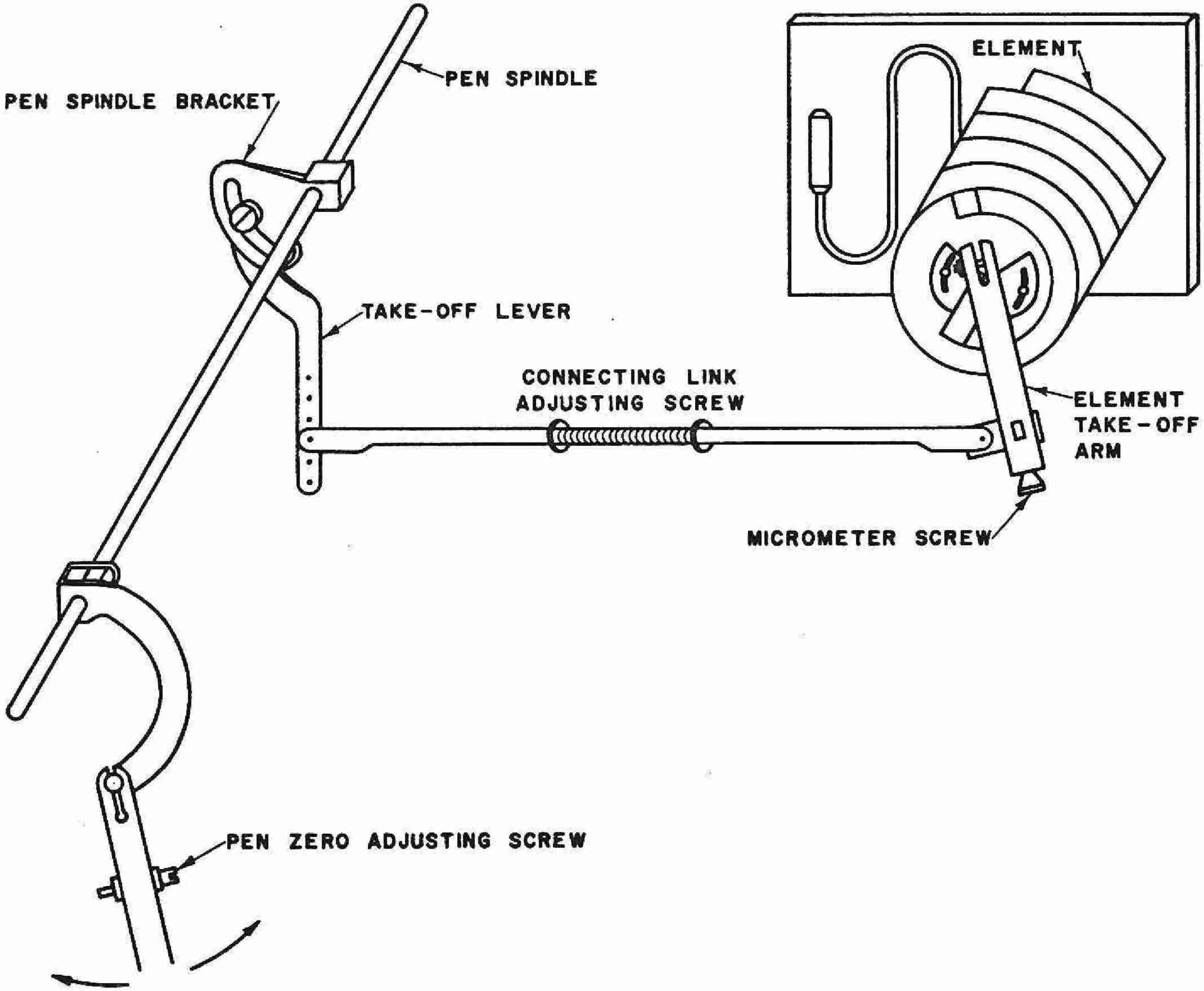

## WIRING DIAGRAM OF TYPICAL METAMETER CIRCUIT

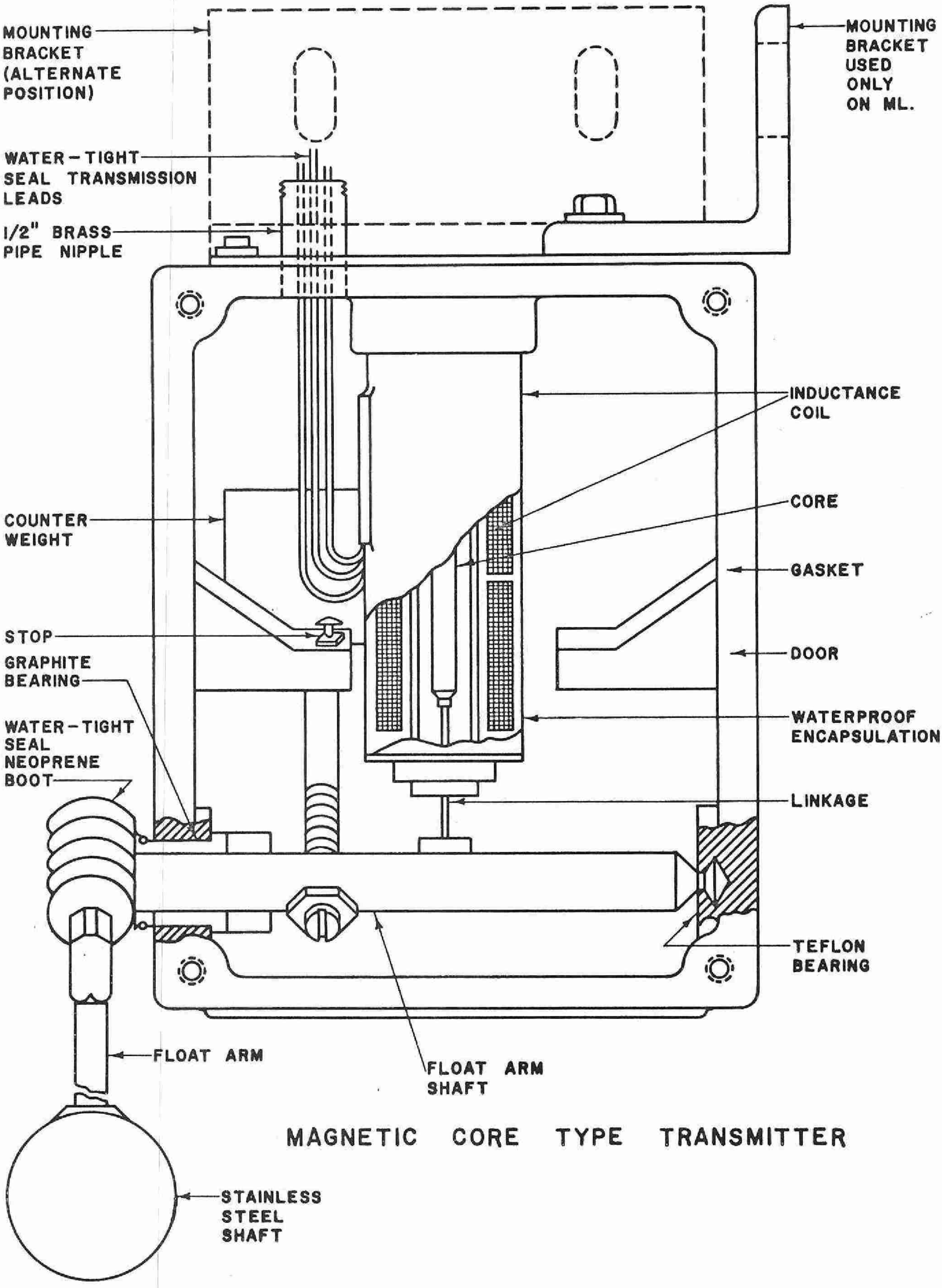


# BELLOWS TYPE DIFFERENTIAL PRESSURE TRANSMITTER



# BOURDON TUBE TYPE OF A DIFFERENTIAL TRANSMITTER






MAGNETIC CORE TYPE TRANSMITTER

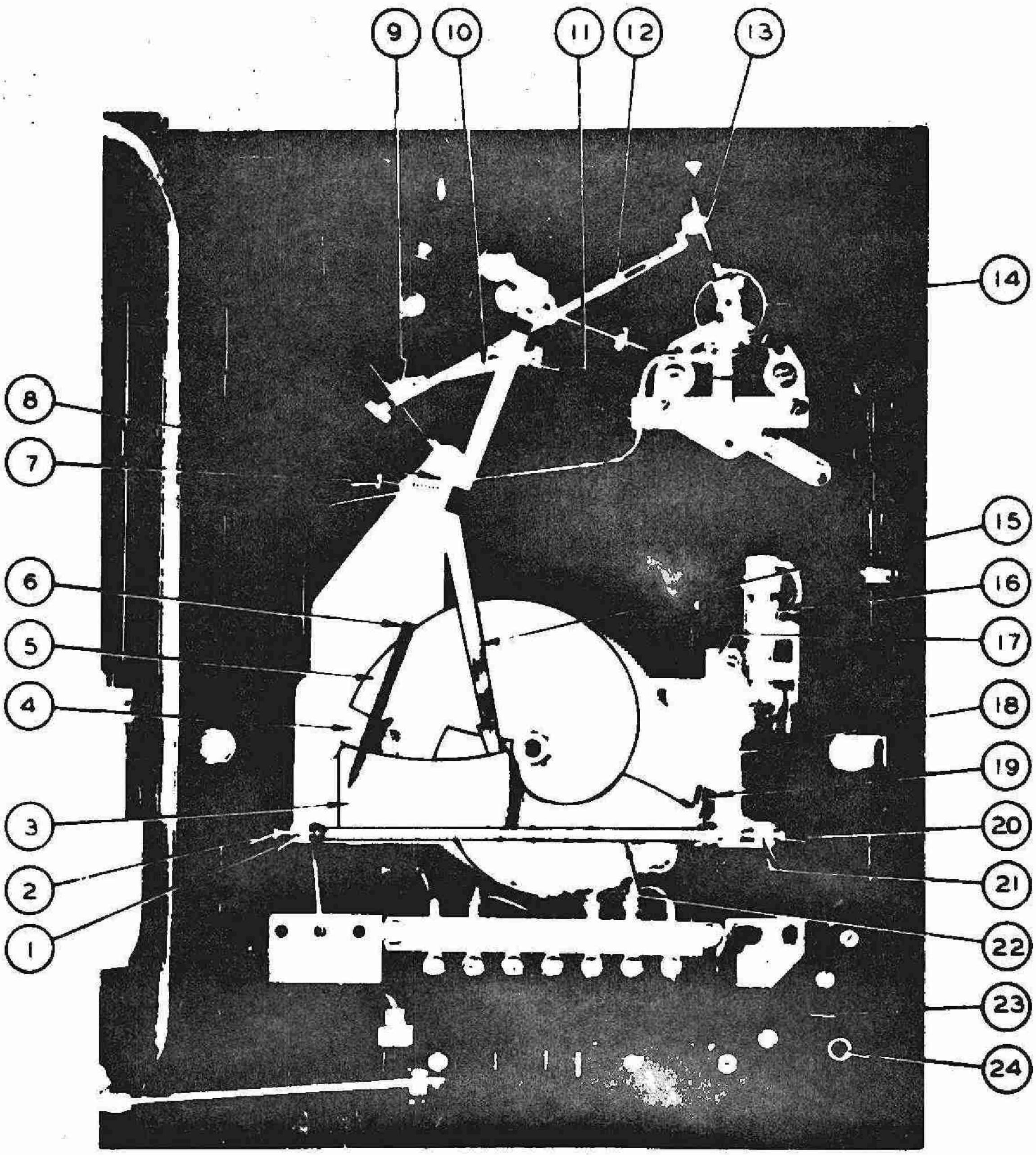
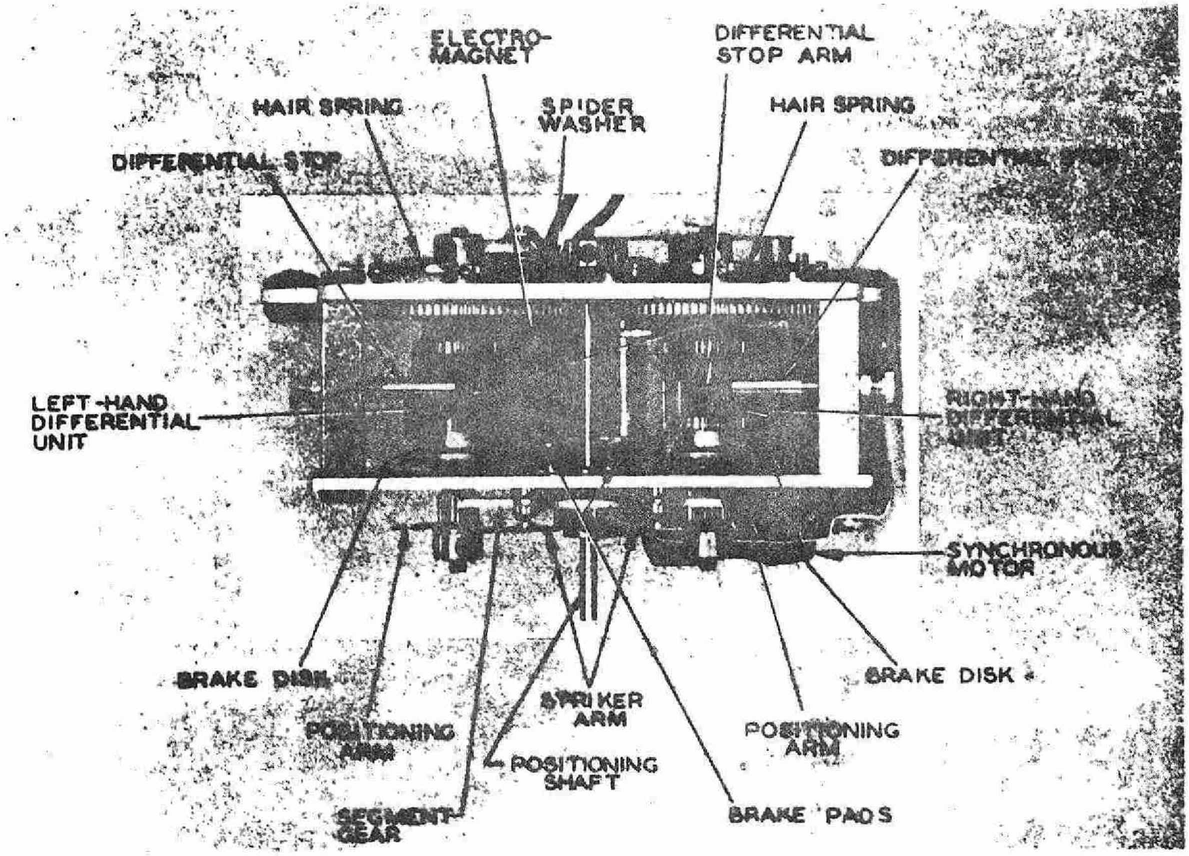


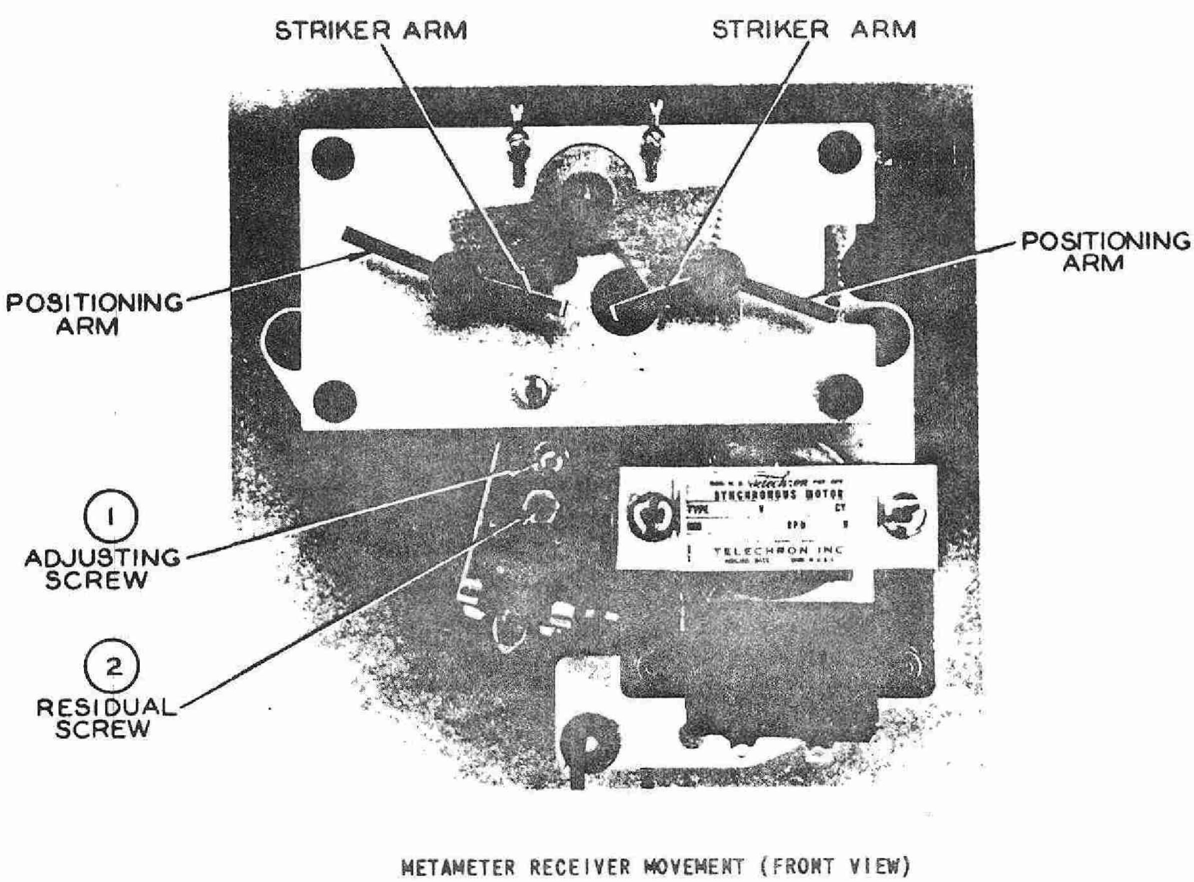

FIGURE 2. TYPICAL METAMETER TRANSMITTER WITH TIMER PLUG ATTACHMENT R14A AND SCALE PLATE REMOVED

CODE TO FIGURE 2

1. Locking Screw
2. Bearing Screw
3. Lifter Plate
4. Fixed Arm
5. Cam
6. Indicating Pointer
7. Zero Adjustment for Cam Follower
8. Locking Screw
9. Span Adjustment for Indicating Pointer
10. Linearity Adjustment for Pointer
11. Zero Adjustment for Indicating Pointer
12. Linearity Adjustment for Cam Follower
13. Span Adjustment for Cam Follower
14. Measuring Element
15. Cam Follower
16. Mercury Switch
17. Permanent Magnet
18. Vane-Arm Assembly
19. Balance Cam
20. Bearing Screw
21. Locking Screw
22. Trip-Plate Shaft
23. Convenient Outlet } Attachment R14A
24. Timer Plug } Optional

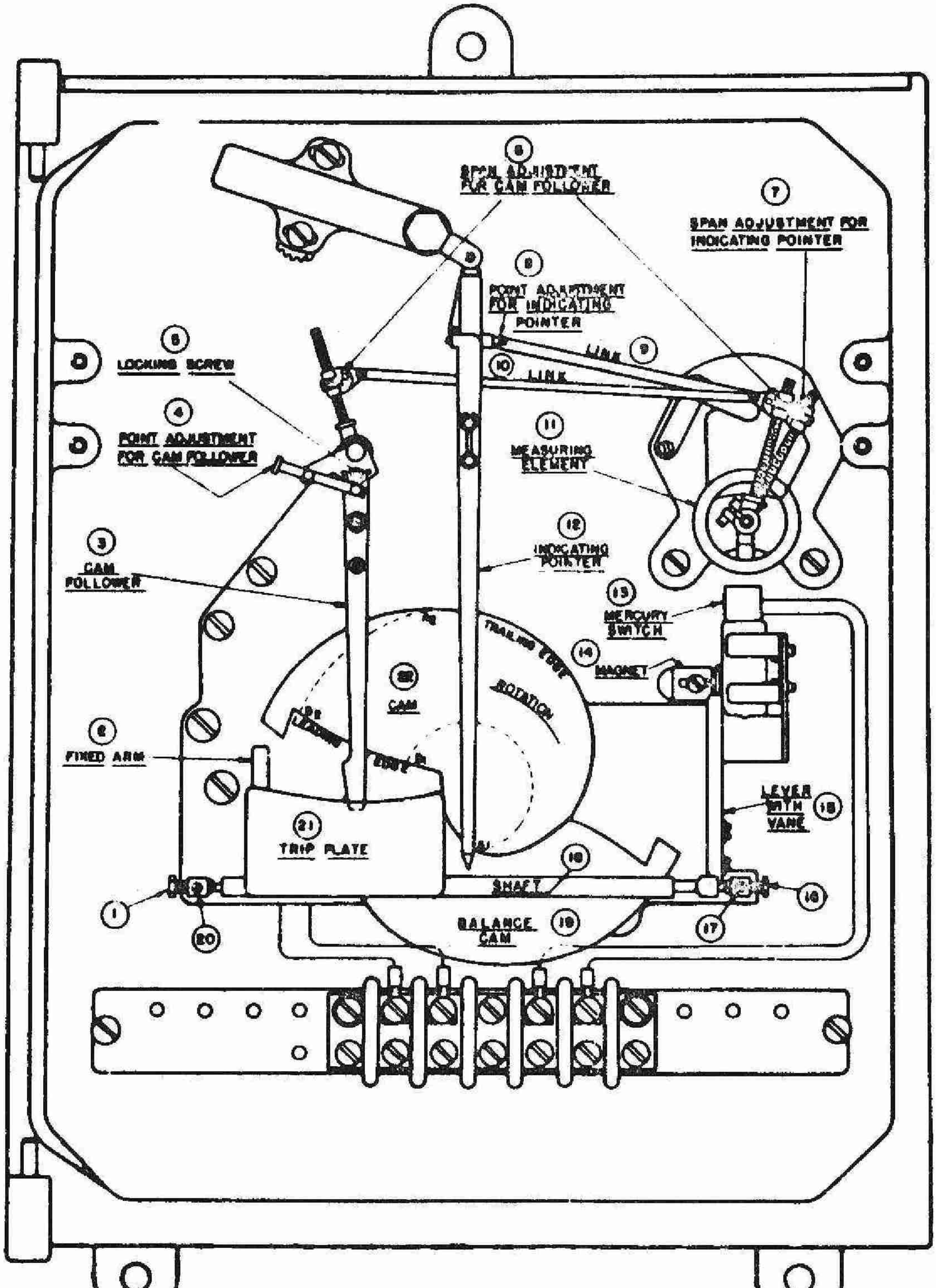



METAMETER RECEIVER MOVEMENT (TOP VIEW)

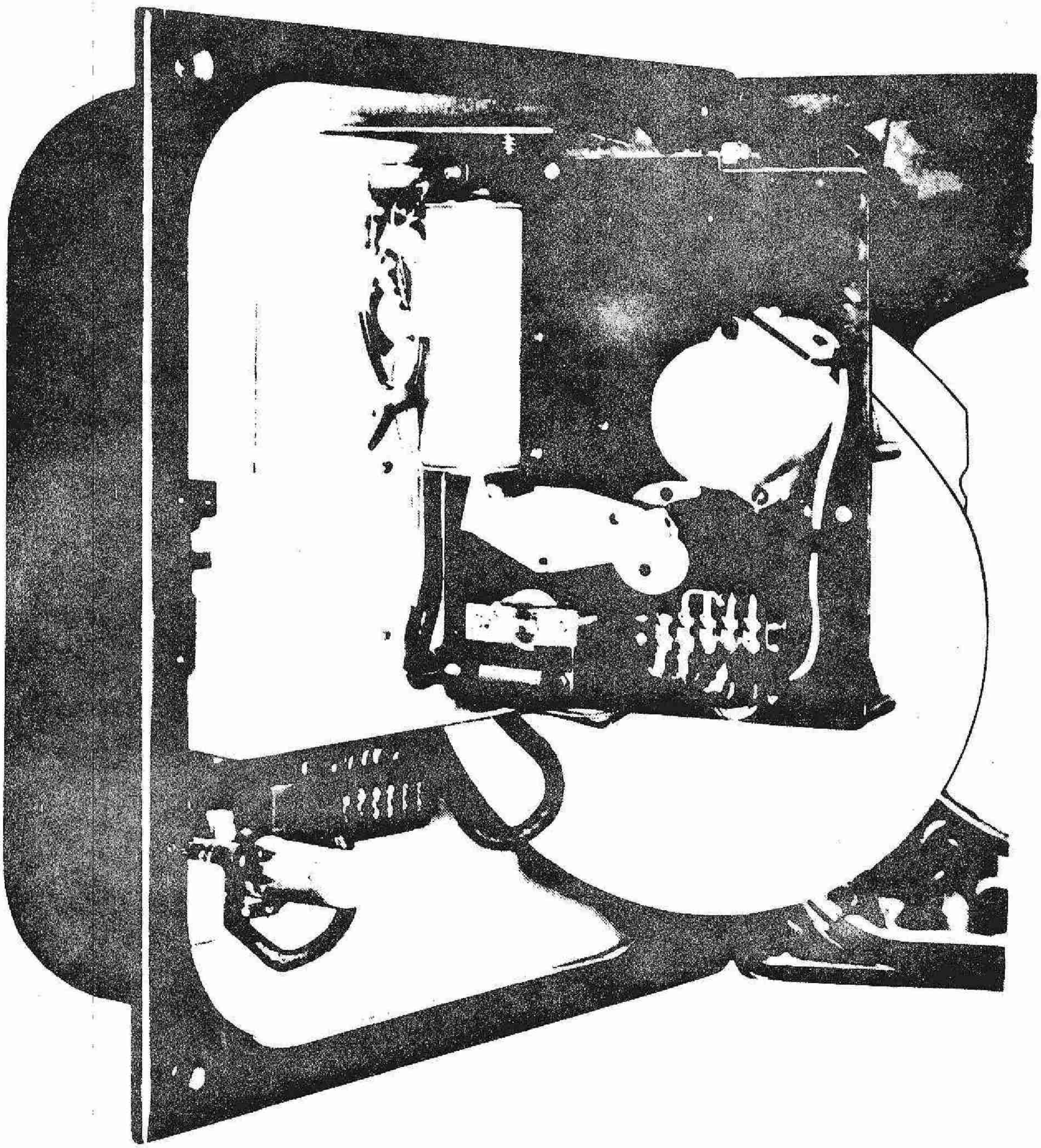



METAMETER RECEIVER MOVEMENT (FRONT VIEW)

# CAM TYPE TRANSMITTER



# MAGNETIC CORE TYPE RECEIVER



# CHLORINATION - PART I

G. R. Trewin

Assistant Director
Division of Sanitary Engineering

## INTRODUCTION

The lecture will cover the basic theory of chlorination as related to the disinfection of water intended for potable uses. In addition, the various methods of determining chlorine residual are detailed, followed by a review of Ontario Water Resources Commission Technical Bulletin 65-W-4.

## PURPOSE OF CHLORINATION

The chlorination of Public water supplies represents the most important process used in the production of potable water. The first and basic reason for chlorination is to provide disinfection. Disinfection refers to the reduction of the bacterial population to a safe level and the elimination of pathogens as contrasted to sterilization which refers to the total destruction of the bacterial population.

The object of disinfection is to kill disease-producing organisms which may have gained entrance into a water supply. The bacteria involved are primarily those causing intestinal (enteric) diseases such as typhoid, the paratyphoids and dysenteries; most other harmful bacteria are not generally considered to be spread by impure waters.

In addition to bacteria, viruses are now being given consideration. It is now believed the virus which causes infectious hepatitis can be water transmitted. In the same regard, the poliomyelitis virus may also be of importance.

## CHLORINE CHEMISTRY

The reactions of chlorine with water and with the many substances that may be in the water and the effect temperature and pH have on these reactions are all related to the performance of the chlorine added.

There are a tremendous number of reactions that can be initiated when chlorine is added to natural waters. It would take considerably more data than we now have to predict exactly what will take place when chlorine is added to the water.

To simplify the ensuing discussion, the majority of materials with which chlorine will react in dilute solutions will be roughly categorized into five groups: inorganic substances, ammonia, amino acids, proteins, and carbonaceous matter.

The first reactions that should be considered are those between chlorine and water (equation 1 and 2). In chemically pure water, chlorine reacts with the water and hydrolyzes to hypochlorous acid (HOCl) and hydrochloric acid (HCl).

Equation 1: $Cl_2 + H_2O \longrightarrow HOCl + H^+ + Cl^-$

Equation 2: $HOCl \rightleftharpoons H^+ + OCl^-$

When the pH is above three and the concentration of chlorine is less than 1000 mg/l, the reaction is, for all practical purposes, irreversible and instantaneous. The hypochlorous acid dissociates to hypochlorite ions ($OCl^-$) and hydrogen ions ($H^+$). The equilibrium condition for this reaction is a function of the pH and temperature as shown graphically in Figure 1. Because the dissociation is so rapid, the equilibrium ratio at any given pH remains constant even though the hypochlorous acid concentration may be decreasing.

Since the oxidizing agents in water are the hypochlorous acid and the hypochlorite ion rather than molecules of elemental chlorine, the unreacted excess has been classified as free available residual chlorine. As the pH of a solution containing 1.0 mg/l of free available residual chlorine is elevated, the oxidation potential decreases as shown in Figure 2. The curve plotted by Chang for 8.7 mg/l of free available residual chlorine is almost identical. The oxidation-reduction potential is a measure of the tendency chlorine has to react with other materials. Unfortunately, it is not a measure of the speed with which these reactions will take place. In essence, as the pH increases, chlorine tends to react with fewer substances, and it is generally accepted that, as the temperature increases, the reactions that do take place will be faster.

The oxidation reactions of chlorine with inorganic reducing agents are generally very rapid. Sulfides, sulfites, ferrous iron, and nitrites are examples of such agents. Some dissolved organic materials also react with chlorine rapidly, but the time required for completion of most organic chlorine reactions is a matter of hours.

The kinetics of the reactions of chlorine with ammonia, amino acids, and proteins, and the products produced by these reactions have been extensively studied. The common goal of this work was to theoretically explain the breakpoint process. Griffin has shown that when chlorine is added to water containing ammonia or ammonia ions, a residual oxidant is obtained. However, when the initial molar ratio of chlorine to ammonia is greater than 1, oxidation of ammonia and reduction of the chlorine starts to take place. When the initial molar ratio of chlorine to ammonia is around 2, all of the free ammonia is oxidized and chlorine reduced if sufficient time is allotted for the reaction. The reactions of chlorine with albuminoid nitrogen were found to produce a form of the breakpoint curve. But, the hump and the breakpoint in the curves were usually less discernible than those obtained with free ammonia.

The conclusion made from research has, essentially established that the reactions of chlorine with ammonia can be represented by equations 3, 4, and 5.

Equation 3: $HOCl + NH_3 \longrightarrow NH_2Cl + H_2O$

Equation 4: $HOCl + NH_2Cl \longrightarrow NHCl_2 + H_2O$

Equation 5: $HOCl + NHCl_2 \longrightarrow NCl_3 + H_2O$

The rate of chlorine substitution and the reaction products are a function of the pH, temperature, time and initial chlorine to ammonia ratio. For pH values less than 5, the reactions between ammonia and chlorine may require several minutes. The actual products of the breakpoint reactions and the mechanics of the reactions are yet to be clearly defined. The amount of dichloramine ($NHCl_2$) formed during the reaction is also questionable. The amount of dischloramine formed is also a function of the temperature, pH, time, and initial ratio of chlorine to ammonia. Fair et al, report that the equilibrium condition between monochloramine and dichloramine can be expressed as follows:

$$\frac{(NH_4^+)\quad(NHCl_2)}{(H^+)\quad(NH_2Cl)2} = 6.7 \times 10^5$$

This relationship for a chlorine to nitrogen molar ratio of 1 is plotted in Figure 3 (Curve A). Curves B and C in Figure 3 are the relationships obtained by Palin. In any event, at pH values below 6, some dichloramine formation is to be expected. Research also indicates that at pH values below 7.5 some nitrogen trichloride formation is to be expected as well.

The oxidation-reduction potential of the chloramines is much lower than that of free available chlorine and is also affected by pH. For pH values between 6 and 8, the chloramine oxidation potential is shown in Figure 2 with a similar curve for a 1.0 ppm combined residual formed with glycine. The influence of the ammonia-chlorine ratio upon the oxidation potential is shown graphically in Figure 4.

The lower oxidation potential of the ammonia chloramines indicate that they are less reactive than free available chlorine. The research on the reactions of free and combined available chlorine with various amino acids also indicates that the chloramines react slower and to a lesser degree.

Figure 5 presents an example of a break-point curve when a 0.5 ppm of dose of ammonia nitrogen is added to a chlorine demand free water. As the chlorine dosage is increased, the ammonia will be oxidized. The break-point, or near complete destruction of the ammonia will occur when the chlorine dosage is between 7.5 and 25 times that of the ammonia; either natural or added. The chlorine dose at the break-point, shown as B in Figure 5, is generally approximately 10 times the original ammonia concentration. The ideal type curve shown in Figure 5 is seldom realized because of the presence of complex organic compounds in the water.

## BACTERIACIDAL EFFECTIVENESS

The primary purpose of the addition of chlorine to water is to destroy bacteria and other micro organisms. Trace amounts of free available chlorine prove to be very effective in this intended purpose. One belief is that the destructive action is a physio chemical one. Another theory postulates that because trace amounts of chlorine are effective, it implies that it must inhibit a key-enzymatic process.

Any change in the state of the chlorine which reduces its oxidation potential as for example, its reaction with ammonia or ammonia derivatives to form combined chlorine residual — reduces the rate at which it reacts with the bacterial cells and decreases its effectiveness as a disinfecting agent.

Available data show that, under most favourable conditions: (a) to obtain equivalent bactericidal action with the same period of exposure, about 25 times as much combined available residual chlorine as free available chlorine residual is required and, (b) to obtain equivalent

bactericidal action with the same amount of combined available chlorine residual as free available residual, a contact period of approximately 100 times as long is required.

Besides the type of residual having an effect on the chlorine residual required to effect disinfection, other factors such as pH, temperature, and type of water will also vary the requirements. See Figure 6 for a residual requirements curve secured in U.S. Public Health Service experiments at temperatures of from 20° to 25° C for 60 minutes with an exposure to combined available residual chlorine and also 10 minutes exposure to a free available residual chlorine. Figure 7 presents 100 per cent kill curves for chlorination as submitted by Butterfield.

CHLORINE RESIDUAL DETERMINATION

There are a number of methods available for determining chlorine residual in water. Four common methods are:

Orthotolidine (OT)
Starch iodide
Palin (DPD method)
Amperometric titration

The simplicity of the orthotolidine test (OT) has lead to its general use at water works plants. Even when a water treatment plant is equipped with newer amperometric titration facilities, check control is usually maintained with the OT method. A four point procedure for performing the OT test is:

1. Draw sample of chlorinated water. The tap should be kept running continuously or for a few minutes before taking the sample. When sample is collected adjacent to a hypochlorinator application point, a large volume sample should be collected over a number of injection cycles.

2. Allow sample to stand for 15 minutes to simulate the required minimum contact period.

3. Use 0.5 ml of orthotolidine (OT) reagent in 10 ml cells, 0.75 in 15 ml cells, and five ml in 100 ml tubes. Place reagent in testing tube; add sample to required volume; and mix. When the temperature of the sample is less than 68°F bring it to that temperature quickly after mixing with the OT.

4. A colour comparison is made when the maximum colour develops.

The above procedure is satisfactory for determining the total available chlorine residual. When the free residual is required the sample must be near 32°F when the OT is added and the colour comparison is made immediately. The orthotolidine-arsenite (O.T.A.) test can also be used to determine the free available chlorine residual.

The starch iodide method of residual determination may be used at sewage treatment plant and also for chlorine concentrations greater than that generally encountered in water works operation. The Palin method, although not generally used, can determine the free residual without refrigeration and cooling. Lack of sensitivity at lower residuals and reagent problems may be restricting factors.

The amperometric titration method of residual determination is to be preferred when complex chlorination programmes are adopted. With this method the free and total available residuals may be determined at any water temperature without refrigeration or warming procedures. With the need for continuous residual monitoring, to ensure the 100 per cent effectiveness of the chlorination process, the related chlorine residual recorder is becoming more important.

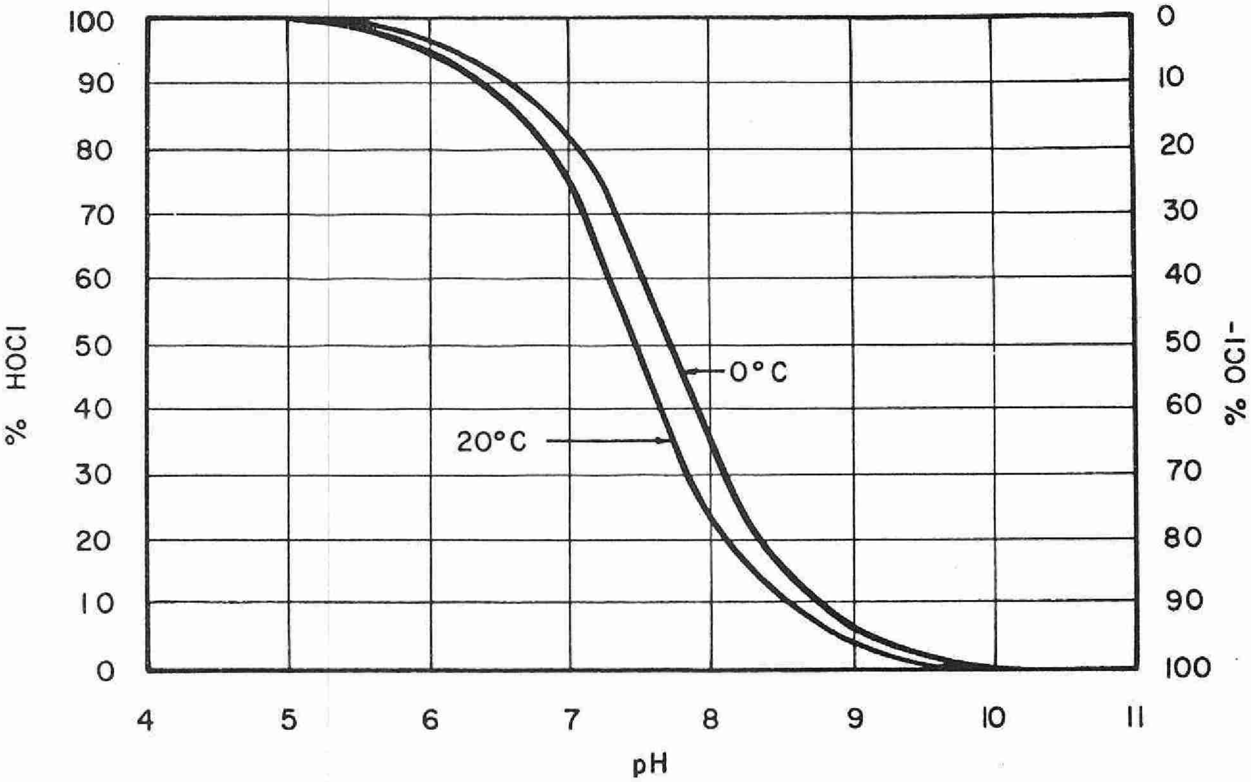



Figure 1

Relative amounts of HOCI and OCI present at various pH values

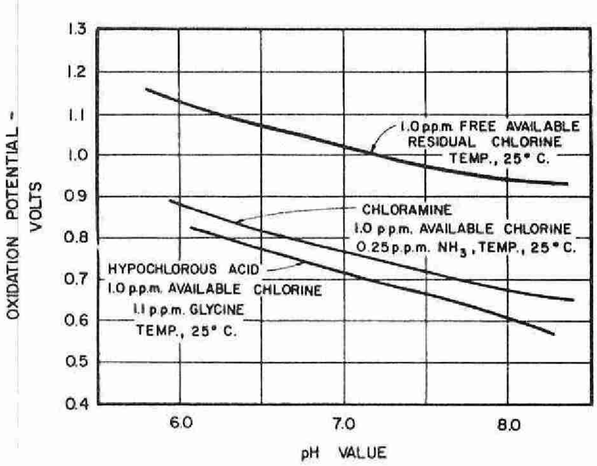



Figure 2

Variation of oxidation potential of solutions containing different compounds of chlorine

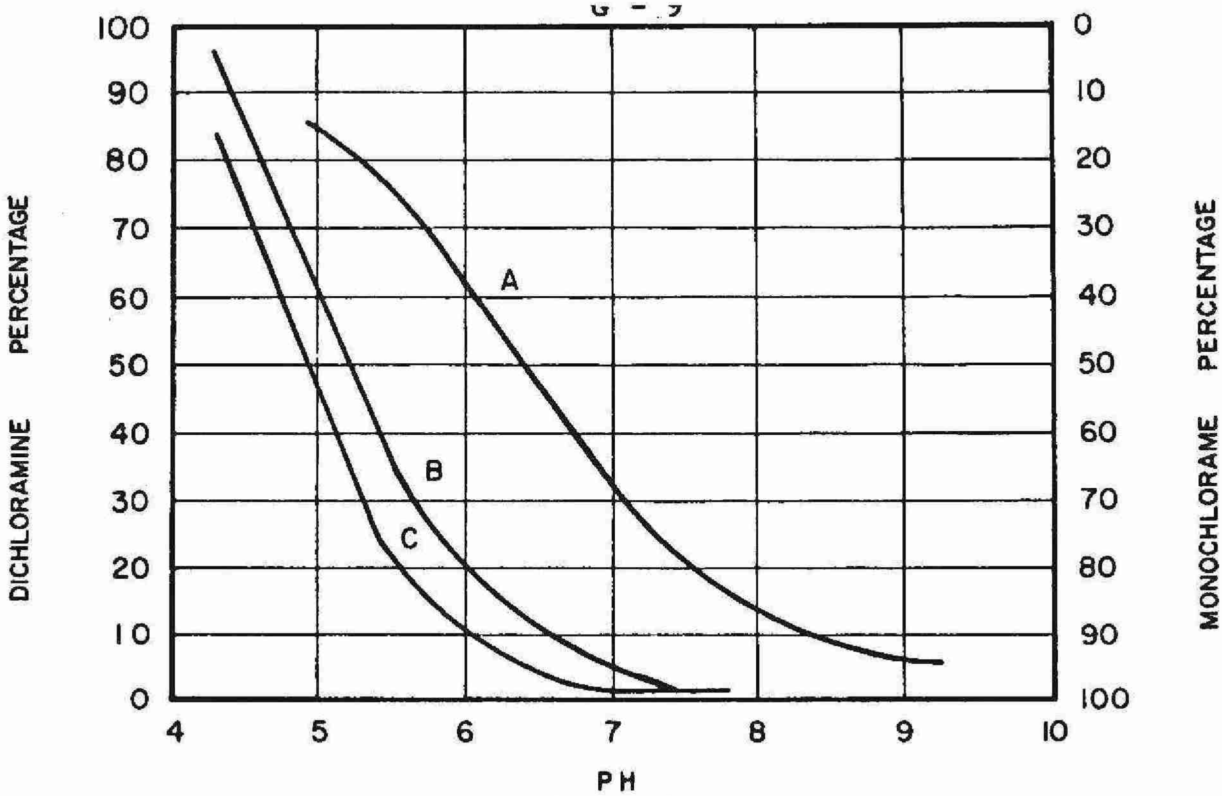



Figure 3

Relationship between $NH_2CI$, $NHCI_2$, and pH
(a) Initial chlorine to ammonia weight ratio 5:1
(b) Initial $CI_2/N$ weight ratio 2.6:1 contact period 10 mins.
(c) Initial $CI_2/N$ weight ratio 5:1 contact period 10 mins.

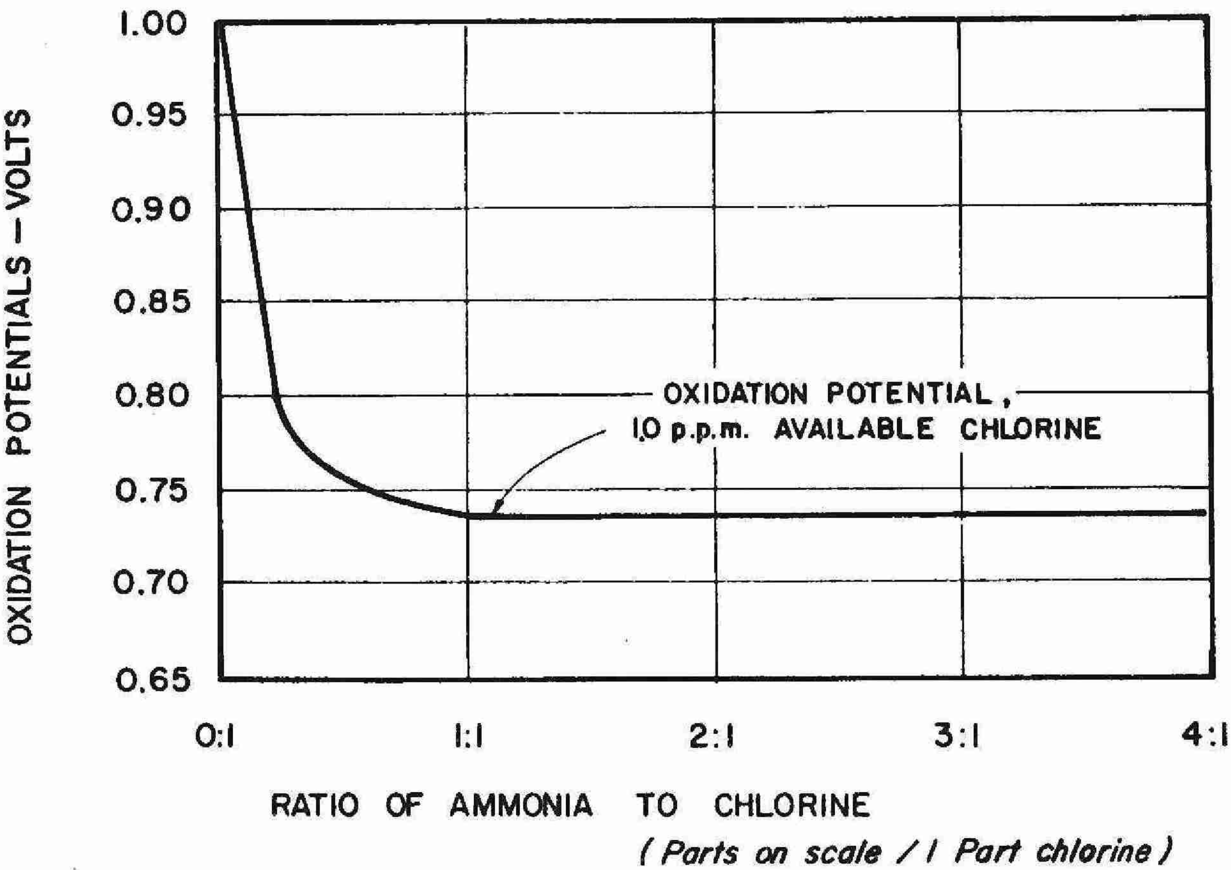
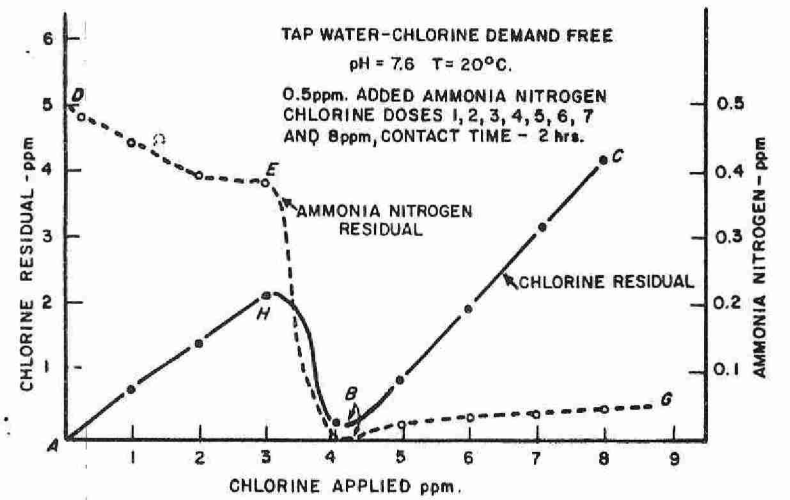



Figure 4

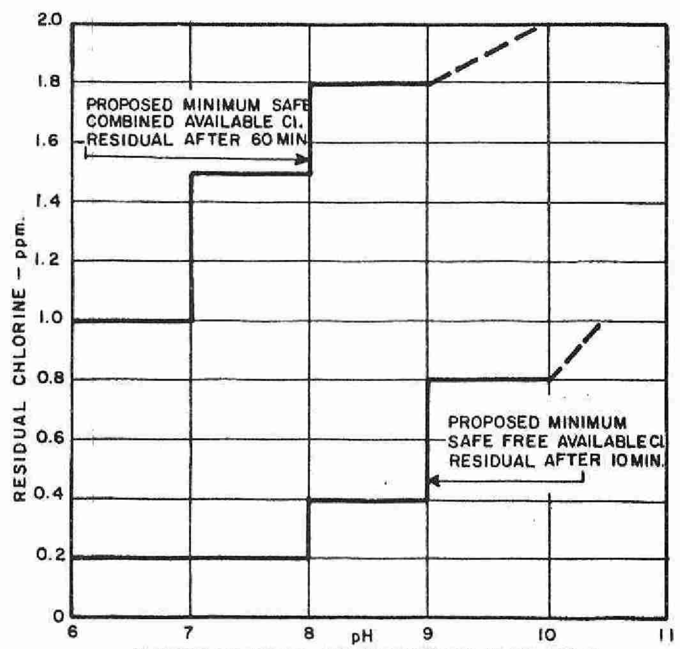
Influence of ammonia: Chlorine ratio upon oxidation potential

FIG. 5



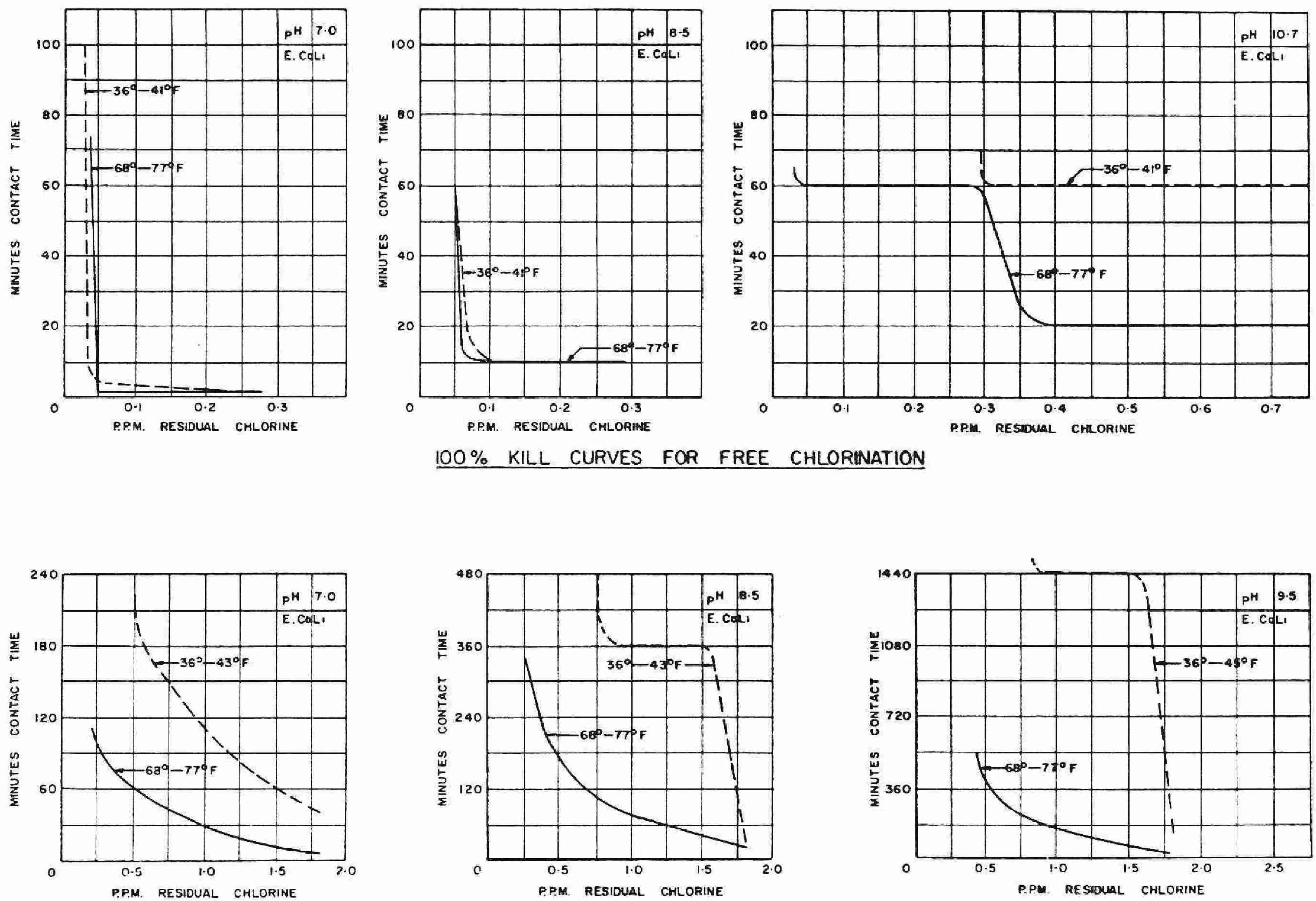

THE BREAK-POINT PROCESS

FIG. 6




MINIMUM FREE OR COMBINED AVAILABLE
CHLORINE RESIDUALS BY BUTTERFIELD.
U.S. PUBLIC HEALTH EXPERIMENTS

# 100% KILL CURVES FOR CHLORINATION




100% KILL CURVES FOR COMBINED CHLORINATION

DIVISION OF SANITARY ENGINEERING
ILLINOIS DEPARTMENT OF PUBLIC HEALTH T.R. 10-2
COMPILED MAY 1947

FIGURE 7

Ontario Water Resources Commission

Division of Sanitary Engineering

# CHLORINATION OF POTABLE WATER SUPPLIES

Technical Bulletin 65-W-4

# CHLORINATION OF POTABLE WATER SUPPLIES

## Index

# CHLORINATION OF POTABLE WATER SUPPLIES

## 1.0 INTRODUCTION

### 1.1 Purpose of Bulletin

The following information provides a minimum standard of design and operation of chlorination facilities. New installations should meet the criteria as set out in the bulletin and an effort should be made to bring existing facilities up to or above the minimum standard in a reasonable length of time.

### 1.2 When Disinfection Required

Treatment by continuous and adequate chlorination is required when the supply is obtained from a surface source; when the supply is exposed to contamination during treatment; when ground water sources are or may become contaminated, as in creviced limestone areas; or where local conditions, such as flooding, indicate the need.

## 2.0 EQUIPMENT

### 2.1 Capacity

Chlorination equipment shall have a maximum feed capacity at least 50 percent greater than the highest expected dosage required to provide a free chlorine residual. In addition each gas chlorinator not supported by standby units of equal capacity shall have a conversion kit sized to double the capacity of the machine.

### 2.2 Chlorinators and Controls

Dependable feed equipment, either of the gas feed or positive displacement solution feed type, may be used for adding chlorine. Automatic proportioning of the chlorine dosage to the rate of flow of the water treated shall be provided at larger plants and at all plants where the rate of flow varies without manual adjustment of pumping rates.

### 2.3 Duplicate Equipment

All chlorination equipment at plants providing chlorination to ensure the safety of the supply shall be installed in duplicate, so as to provide standby units for ensuring uninterrupted operation. In addition, spare parts consisting of at least the commonly expendable parts such as glassware, rubber fittings, hose clamps, and gaskets, should be provided for effecting emergency repairs.

For a multi-well supply system requiring chlorination for disinfection, the standby requirement may be covered by one portable unit.

2.4 Weigh Scales

When gas feed chlorinators are employed, a set of corrosion resistant scales should be made available for weighing the chlorine cylinders serving each operating chlorinator.

2.5 Hypochlorite Solution

Where a powdered product is used, hypochlorite solutions should be prepared in a separate tank. The solution is allowed to settle so that only a clear liquid is withdrawn to the solution storage tank and to the hypochlorinator.

2.6 Safety Equipment (Gas application only)

Each plant shall have readily available a self-contained or air-supplied type of respiratory protective equipment. Smaller installations may make arrangements with a local fire department or other agency for the loan of the required equipment on an emergency basis.

When a canister type mask is used in place of a self-contained or air-supplied unit the operators must be made fully aware of its limitations and the location of more adequate equipment.

One respirator shall be immediately available, located in a conspicuous location outside the area of probable contamination.

Protective clothing including gloves, goggles and safety shoes shall be available for persons handling chlorine.

Deluge type safety showers and eye wash fountains shall be available in case of accident.

Preferably weigh scales for 150 pound cylinders shall be recessed in floor.

Safety chains shall be used to retain 150 pound cylinders, either in storage or on weigh scales, in a safe upright position.

2.7 Building Detail (Gas application only)

Gas chlorine equipment - chlorinators, weigh scales, chlorine cylinders - must be located in an isolated building, room or rooms. In larger installations the storage and scale facilities should be in a room separated from the chlorinators. The construction of the room or rooms should be of fire resistive material and have concrete floors.

Ton cylinders shall be stored on their sides on level racks, between four and eight inches off the grade. Chlorine should not be stored below ground level and the cylinders must be protected from excessive heat, dampness, and mechanical damage.

Areas containing chlorine or chlorinator equipment shall be clearly marked "DANGER! CHLORINE STORAGE" or "DANGER! CHLORINE FEED EQUIPMENT" as applicable.

The exit doors shall be hinged to open outwardly. There shall be two or more exits if the distance of travel to the nearest exit exceeds 15 feet.

Continuous mechanical ventilation at the rate of three air changes per hour shall be provided, or, screened openings to the outdoors shall be provided within six inches of the floor in the ratio of one square foot per 500 square feet of floor area. Similar openings shall be provided in or near the ceiling. The openings shall be distributed to produce the maximum air circulation across the floor. Secondly, provision for emergency mechanical ventilation should be made sufficient to produce 30 air changes an hour taking suction at a maximum of three feet above floor level.

The temperature in the storage and scale room should never be higher and preferably slightly lower than that in the chlorinator room. The gas lines between the scales, chlorinators and injectors should not be located on an outside wall or in a location where low temperatures may be encountered.

2.8 Testing Equipment

All installations must be equipped with a permanent standard chlorine residual comparator test kit. When free residual chlorination is mandatory an amperometric titrator is also required.

In larger installations, or where poor raw water quality and/or minimum supervision indicates a hazard, a chlorine residual recorder is required. The chlorine residual recorder shall be equipped with a low residual alarm and installed to measure the chlorine residual in the water leaving the plant.

## 3. 0 ROUTINE OPERATION

### 3. 1 Chlorine Residual

For complete water treatment plants which effect both pre- and post-chlorination, or when a minimum of two hours contact time is assured before distribution after the application of chlorine, or where free residual chlorination is practised, or for ground, or protected surface water supplies, the minimum chlorine residual shall be 0. 2 p. p. m. For other water supplies the minimum chlorine residual shall be 0. 5 p. p. m.

The chlorine residual test is performed on a sample of the plant or pipe line effluent, after it has been held for 15 minutes.

When ground water sources are free from possible contamination and are proved to be bacteriologically safe they may be exempted from chlorination.

As individual circumstances demand the minimum requirements for chlorine residual may be increased.

Free residual chlorination may be made mandatory and is preferred for all supplies that can economically practise it.

A free chlorine residual may be defined as a condition where a minimum of 80 percent of the total available chlorine residual is in the free state.

It is suggested that where possible a chlorine residual be maintained in all active parts of the distribution system.

### 3. 2 Chlorine Application Points

Where possible pre- and post-chlorination shall be practised. When only post-chlorination is possible free residual chlorination should be considered, and a minimum contact time of 15 minutes, before the first possible consumer, must be provided in a pipe line, reservoir, or pressure tank.

### 3. 3 Chlorine Residual Test

The following procedure shall be followed in performing the orthotolidine chlorine residual test.

1. Draw sample of chlorinated water. The tap should be kept running continuously or for a few minutes before taking the sample.

2. Allow sample to stand for 15 minutes to simulate the required minimum contact period.

3. Use 0. 5 ml of orthotolidine (O. T.) reagent in 10 ml cells, 0. 75 in 15 ml cells, and five ml in 100 ml tubes. Place reagent in testing tube; add sample to required volume; and mix. When the temperature of the sample is less than 68°F bring it to that temperature quickly after mixing with the O. T.

4. A colour comparison is made when the maximum colour develops.

5. The test results are recorded in the plant records and the necessary alteration is made to the chlorine application rate.

The above procedure is satisfactory for determining the total available chlorine residual. When the free residual is required the sample must be near 32°F when the O. T. is added and the colour comparison is made immediately. The orthotolidine-arsenite (O. T. A.) test can also be used to determine the free available chlorine residual.

The accuracy of a chlorine residual recorder shall be checked daily. This is accomplished using either the amperometric titration or orthotolidine colourimetric test procedures. The results of the check are inscribed on the recording chart along with the date and operator's initials, opposite a mark showing the time of the check.

The chlorine residual test must be performed frequently enough to ensure that an adequate chlorine residual is maintained at all times. Such points as raw water quality and a resultant variation in chlorine demand, and changing flow rates must be taken into consideration. When a residual recorder alarm system is used the testing frequency may be reduced.

3. 4 Records

Minimum records shall include:

1. daily records of the chlorine used and scale readings,
2. results from all chlorine residual tests,
3. the flow rate and chlorine feed rate at the time of testing,

4. water used and chlorine dosage in p. p. m. on a daily basis,
5. detail on chlorine cylinder changes, orders and chlorine on hand, and
6. monthly and yearly summaries of chlorine consumption and feed rates.

## 4.0 EMERGENCY OPERATION

Where chlorination is required for disinfection purposes a continuous feed of chlorine must be assured. For this type of service the operating authority shall develop a standby operating procedure to cover emergencies. The procedures developed shall be posted in a prominent location in the plant and all operators shall be made aware of the information thus given.

The emergency information shall include:

1. the order not to pump unchlorinated water to the distribution system,

2. the name, address and telephone number of -
   (a) senior supervisory personnel,
   (b) medical officer of health,
   (c) Ontario Water Resources Commission, Toronto, telephone number - 416-365-1491,
   (d) chlorinator service company, and
   (e) chlorine supplier,

3. the order to notify immediately the Ontario Water Resources Commission and the medical officer of health if unchlorinated water is directed to the distribution system,

4. details on emergency chlorination procedures, and

5. a statement on operator responsibility.

When emergency chlorination is provided the minimum chlorine residual in the water leaving the plant shall be 1. 0 p. p. m.

When unchlorinated water has been directed to the distribution system, and until direction is obtained from the Ontario Water Resources Commission, the chlorine feed rate shall be increased and a programme of hydrant flushing initiated to provide a minimum chlorine residual of 1. 0 p. p. m. in the whole of the distribution system. When increasing the chlorine residual or carrying out an extensive hydrant flushing programme, notify all customers that may be adversely affected.

## 5. 0 ADVERSE BACTERIOLOGICAL RESULTS

When the results from bacteriological samples collected from the distribution system do not meet the requirements of the Ontario Water Resources Commission Drinking Water Objectives, the Ontario Water Resources Commission and the local medical officer of health shall be notified. The Ontario Water Resources Commission will recommend corrective action suited to the individual circumstances. The recommendation may include one or a number of the following procedures:

(a) the disinfection, for a 24-hour period, of the distribution system with a solution having a starting strength of 50 p. p. m. of available chlorine;

(b) the initiation of chlorination procedures on an unchlorinated supply;

(c) an increased chlorine residual requirement along with a distribution system flushing programme;

(d) the collection of further samples;

(e) a recommendation to the medical officer of health that a boil water order be issued.

## 6. 0 DISINFECTION OF NEW WORKS

### 6. 1 Preparation

Before disinfection is attempted, all surfaces must be thoroughly cleaned. Pipe lines are flushed with potable water until a turbidity-free water is obtained at all ends. Reservoirs are to be flushed with water and brushed as required, to obtain clean surfaces.

As chlorine is a surface active disinfectant it may not penetrate crevices or particles of debris. Therefore, a thorough cleaning is necessary if the disinfection programme is to be effective.

### 6. 2 Disinfection

Disinfection may be accomplished by one of the following procedures.

1. All surfaces shall be in contact, for a period of 24 hours, with a chlorine solution having a starting strength of 50 p. p. m. available chlorine.

2. All surfaces shall be in contact, for a period of 24 hours, with a chlorine solution of sufficient strength to provide an available chlorine residual of 10 p. p. m. at the end of the contact period.

3. To conserve water and chemical, reservoirs may be disinfected by spraying all surfaces with a chlorine solution having a starting strength of 250 p. p. m. available chlorine. Special protective clothing and self-contained or air-supplied type respiratory must be used by personnel performing the spray procedure.

4. When surface conditions are not ideal, such as will be encountered in used works, special disinfection procedures will be required. This could include the maintenance of a chlorine residual for an extended period of time.

6. 3 <u>Testing</u>

After disinfection, and when the chlorine residual in the treated works is at or below the normal operating level, bacteriological samples shall be collected. When a 0. 2 p. p. m. or greater available chlorine residual is to be maintained in or after the new works, one set of satisfactory bacteriological results shall be obtained before the system is placed into operation. Otherwise, a minimum of two and preferably three consecutive sets of coliform free results shall be obtained before the works are used.

# REMOVAL OF HYDROGEN SULPHIDE

# FROM MUNICIPAL WATER SUPPLIES

by A. Oda, P. Eng.
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Hydrogen sulphide is a colourless gas that has an offensive odour resembling "rotten eggs". It is sometimes found in ground waters derived from some wells and so-called sulphur springs located in certain regions throughout Ontario. Its presence in any drinking water supply, even in trace quantities, is highly undesirable as it imparts objectionable tastes and odours to the water and may lead to other nuisance problems in the distribution system. Therefore, hydrogen sulphide must be completely eliminated from the water before it reaches the consumer.

## PROPERTIES OF HYDROGEN SULPHIDE

Chemical Formula - $H_2S$

Physical

Colourless.
Odour of rotten eggs.
Gaseous substance which is slightly heavier than air.
1 liter weighs 1.54 gm.
Moderately soluble in water.
Behaves like most normal gases; that is, its solubility decreases if the temperature of the water is increased.

Chemical

Burns with a blue flame.
Very toxic in air.
Maximum safe concentration in air is estimated to be about 13 ppm.
Reacts with metals to form sulphides.
Enhances the corrosive nature of water even in very small concentrations.

Where is $H_2S$ found?

Hydrogen sulphide is generally more common to well supplies than to surface supplies. It is likely to be found in water obtained from wells located in Boulder clay, limestone-gypsum areas or near "sour gas" producing oil fields. It may also be found in highly mineralized ground waters, particularly those with relatively high sulphate content. Wells located in the vicinity of so-called "sulphur springs" and some mine fields may yield waters with considerable amounts of hydrogen sulphide.

How is $H_2S$ formed?

Hydrogen sulphide can be produced either chemically or by the action of anaerobic bacteria on certain substances present in the water. In well supplies, occasionally in some surface water supplies, the waters may be contaminated with alkaline or metallic sulphides as a result of deterioration of organic substances or from miscellaneous sources of industrial pollution. Under these conditions, carbon dioxide dissolved in the water will react with these sulphides and form hydrogen sulphide.

In most water supplies, hydrogen sulphide is usually present in trace quantities. It is formed from the decomposition of certain organic substances and sulphates under anaerobic conditions. Two groups of bacteria are responsible for the production of hydrogen sulphide:

(a) Sulphur Bacteria

These organisms are found in mineral sulphur springs and waters polluted with sewage. They are capable of breaking down organic substances especially those containing sulphur and proteins and forming hydrogen sulphide in the absence of oxygen.

(b) Sulphate-reducing Bacteria

These organisms are capable of converting inorganic sulphates into hydrogen sulphide under anaerobic conditions.

What are some of the problems associated with $H_2S$?

(1) Hydrogen sulphide as gas is deadly and reacts in the same way as carbon monoxide and hydrogen cyanide. Maximum safe concentration in air is estimated to be about 13 ppm. However, in water, it is not considered to be as toxic. Waters containing hydrogen sulphide are often used for health drinks and also for bathing purposes at health spas.

(2) Trace quantities of hydrogen sulphide cause objectionable tastes and odours in potable water supplies. When present in concentrations over 1 ppm, this odour becomes objectionable in water. Some persons may even detect its presence in concentrations as low as 0.35 ppm. The following table* gives the recommended limits suggested for the concentration of hydrogen sulphide in water used for various industrial purposes.

| Industrial Use | Recommended Limit in ppm |
|---|---|
| Baking | 0.2 |
| Boiler Feedwater | |
| 0 to 150 psi | 5 |
| 150 to 250 psi | 3 |
| over 250 psi | 0 |
| Brewing | 0.2 |
| Carbonated Beverages | 0.0 to 0.2 |
| Confentionary | 0.2 |
| Cooling Water | 5.0 |
| Food Canning and Freezing | 1.0 |

(3) Hydrogen sulphide increases the corrosive character of water. This in turn, may affect the water quality and cause discolorations and staining problems in the distribution system.

(4) Hydrogen sulphide will attack various metals and other materials used in the manufacture of water mains and plumbing fixtures.

*McKee, J.E. and Wolf, H.W. WATER QUALITY CRITERIA, 2nd. Edition, State Water Quality Control Board, California Publication, No. 3-A, 1963.

It reacts with iron and steel in water pipes to form suspensions of iron sulphide which are responsible for "black" water problems. As a result of sulphide corrosion, water pipes may become badly clogged.

(5) It has been reported that in some instances, small concentrations of hydrogen sulphide in water have damaged greensand zeolites in iron removal plants so that they can no longer be reconditioned.

(6) Hydrogen sulphide may react or interfere with the action of corrosion inhibitors. This means that greater dosages of chemicals may be needed to accomplish the desired treatment for corrosion control. In some instances, the cost of corrosion protection becomes prohibitive.

## METHODS OF REMOVAL

There are several methods of treatment that could be used for the removal of sulphides in water supplies. Since sulphides may be present in the form of both metallic sulphide and gaseous hydrogen sulphide, it may be necessary to utilize both physical and chemical processes in order to achieve complete removal.

If the water supply contains relatively high concentrations of sulphides, it is more practical to consider some form of aeration as a part of the treatment process. However, not all of the sulphides can be removed by aeration alone. Therefore, in order to remove the last remaining traces of sulphide, the water must be treated with chemicals after aeration.

### Aeration

Hydrogen sulphide is slightly soluble in water. By aeration, it is released as a gas and then removed. Also, a portion of the sulphides may be eliminated by oxidation into free sulphur upon contact with oxygen.

Aeration is primarily a mechanical process in which the water is brought into intimate contact with air. Two general methods of aeration are employed. In one method, water, in small droplets is allowed to fall through the air such as in coke tray (Figure 1) or an aerator using

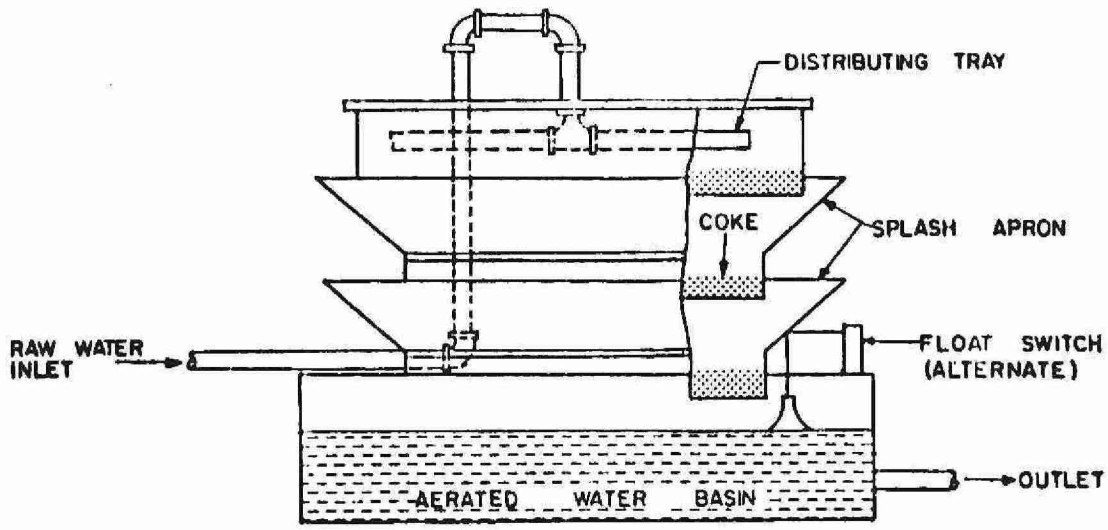


FIGURE 1

COKE TRAY AERATOR (Courtesy of Permutit Co.)

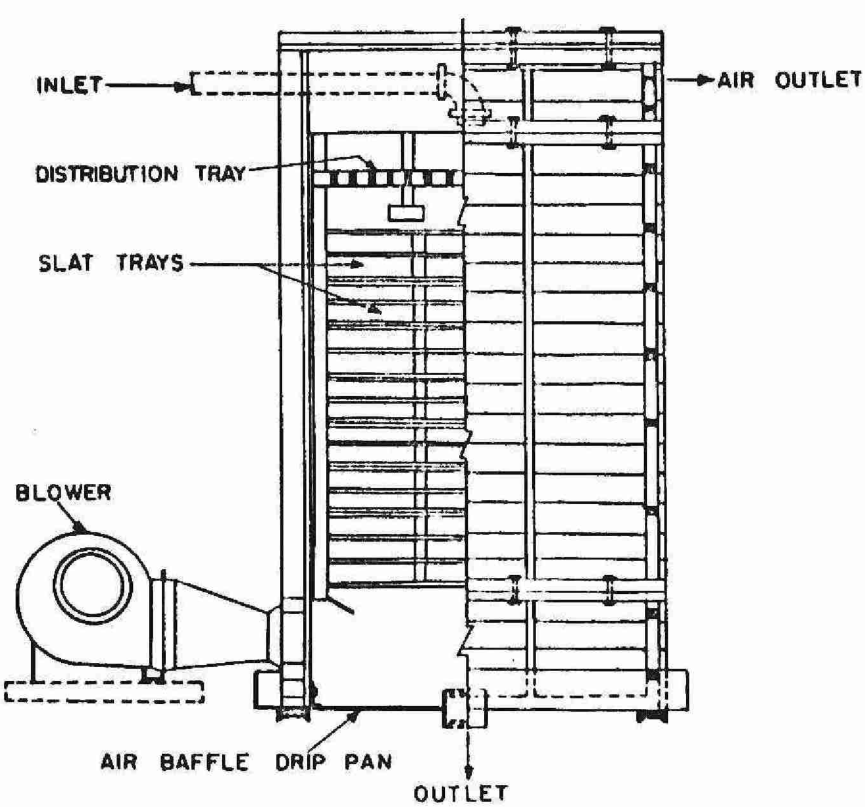


FIGURE 2

FORCED-DRAFT AERATOR (Courtesy of Infilco Co.)

natural ventilation. This type of aeration can be accomplished by using various cascading and forced draft type aerators (Figure #2). In large waterworks, this method of aeration is most commonly used.

The second method of aeration is known as the air diffusion method. Air is bubbled up through a solid body of water by means of diffusers. In smaller waterworks, a hydro-pneumatic tank is used. This is a pressurized tank in which compressed air is introduced to the water through a nozzle or a grid system located at the bottom of the tank. Hydrogen sulphide gas released from the water along with excess air is expelled from the tank through the air relief valves.

Aeration with pH Reduction

A complete removal of hydrogen sulphide from water is not readily obtained by aeration alone. At higher pH values, sulphides are present in the water chiefly as alkaline sulphide and therefore cannot be removed by aeration alone. Data in the table * below show the relationship of pH and percentages of total sulphides available as hydrogen sulphide.

PERCENTAGE OF TOTAL SULPHIDE PRESENT AS $H_2S$

| pH | Percent $H_2S$ |
|---|---|
| 5.0 | 98 |
| 5.4 | 95 |
| 6.0 | 83 |
| 6.5 | 61 |
| 7.0 | 33 |
| 7.5 | 14 |
| 8.0 | 4.8 |
| 9.0 | 0.5 |

* Pomeroy, Richard, Hydrogen Sulphide in Sewage, Sewage Works Journal, Vol. 13, No.3, p. 498, (May 1961)

These data show that a greater percentage of total sulphide is present as gaseous $H_2S$ at lower pH values. Therefore, by reducing the pH of the water to the range of pH 4 to 5, nearly all of the sulphides can be converted into a gaseous form which is more effectively removed by aeration.

In recent years, flue gases have been used for the treatment of sulphurous waters. These gases contain about 13% carbon dioxide, which will reduce the pH value of the water sufficiently to liberate hydrogen sulphide. The quantity of gas required will depend upon the alkalinity of the water supply being treated.

A special type of equipment known as a hydrogen sulphide degasifier is available for this purpose. It consists of a double stack, which is essentially two forced draft aerators placed one on top of the other, with a water seal separating the upper carbonating chamber from the lower aeration chamber. The flue gas is introduced at the bottom of the upper chamber and mixed countercurrently with the falling droplets of influent water. The carbon dioxide in the flue gas reduces the pH of the water and this, in turn, converts the sulphides into hydrogen sulphide. The lower section is similar in design to the carbonating chamber. Here, the air moving countercurrently against the downward flow of water, provides additional scrubbing for the removal of carbon dioxide and any residual hydrogen sulphide in the water.

Reduction in pH of the water may also be obtained by feeding mineral acid prior to aeration. The feed of acid can be controlled to obtain the desired pH reduction. A major disadvantage of this method of treatment is that some adjustment must be made in the pH of the water after treatment.

By combining pH reduction with aeration, the size of the forced draft aerator can be reduced considerably with a more efficient removal of hydrogen sulphide.

With this method, some precipitation of colloidal or free sulphur can be expected, especially if the water supply contains a high level of sulphides. In order to provide water of good clarity, further treatment by means of coagulation and filtration may be necessary.

## Chlorination

Although it is possible to reduce hydrogen sulphide to a very low concentration by means of aeration and aeration with pH reduction, these methods will not eliminate it completely. In some water supplies, hydrogen sulphide even in trace quantities, is undesirable because it will result in objectionable tastes and odours and increase the corrosive characteristics of the water. Therefore, it is necessary to employ chemical methods in order to remove all of the remaining traces of hydrogen sulphide.

Complete removal of hydrogen sulphide from water can be best accomplished by means of chlorination or by a combination of aeration and chlorination.

The reaction between chlorine and hydrogen sulphide can be represented by the following equations:

$$H_2S + Cl_2 = 2\ HCl + S \quad (1)$$

hydrogen sulphide + chlorine = hydrochloric acid + sulphur

$$H_2S + 4Cl_2 + 4H_2O = H_2SO_4 + 8\ HCl \quad (2)$$

hydrogen sulphide + chlorine + water = sulphuric acid + hydrochloric acid

In the first reaction represented by equation (1), hydrogen sulphide is oxidized to free sulphur by chlorine. Theoretically, 2.1 ppm of chlorine are needed to oxidize 1 ppm of hydrogen sulphide. The sulphur produced is in the form of a fine colloidal precipitate which may affect the clarity of water. In addition, it may be converted back into hydrogen sulphide by the action of certain micro-organisms in the distribution system. Therefore, the precipitated sulphur should be removed by coagulation and filtration, especially if the water contains fairly high concentrations of hydrogen sulphide.

Equation (2) shows the result of a reaction using larger amounts of chlorine to oxidize hydrogen sulphide. The latter is oxidized further to sulphuric acid without any formation of sulphur. In this reaction, 8.4 ppm of chlorine are required to remove each ppm of hydrogen sulphide. It can be seen that larger quantities of chlorine are needed for a complete oxidation of hydrogen sulphide and this means that the cost of treatment will also be increased. Consequently, for water

supplies with high concentrations of sulphide, a more economical method is to remove as much hydrogen sulphide as possible by aeration with reduced pH and then utilize chlorination for complete removal.

### Anion Exchange

Anion exchange resins have been developed which are applicable for the removal of hydrogen sulphide from water supplies. These are highly basic resins which will adsorb sulphide, sulphate and other ions. They can easily be regenerated with salts and/or sodium bicarbonate depending upon the pH of the water.

At the present time, the application of these resins for hydrogen sulphide removal has been limited to domestic uses because they are only capable of handling low capacity and low flow rates. The water to be treated must be iron free and preferably, low in hardness.

The equipment is similar in design to a pressure type water softener containing ion exchange materials. One of its main advantages is that this equipment can be easily inserted into a water supply without breaking the line pressure and therefore no oxygen needed to be added to the water for hydrogen sulphide removal. A low cost regenerant can be used. Another feature is that it is also possible in some cases to convert some of the existing zeolite softeners to perform both functions of water softening and hydrogen sulphide removal into one operation.

## ANALYSIS FOR SULPHIDES

In most water supplies, hydrogen sulphide is usually present in amounts less than one ppm and more likely to be in the range of a few tenths or hundredths of one ppm. In order to obtain meaningful data, it is necessary to analyze the water at the time of sampling. In some instances, it is possible to "fix" the sample for sulphides at the source and then bring it back to the laboratory for analysis.

The fixing reagents consist of 2N zinc acetate solution (220 gm $Zn\ (C_2H_3O_2)\ .2H_2O$ dissolved in 1 litre of distilled water). 2ml of this solution per litre is placed in the collecting bottle. Samples must be taken with a minimum of aeration because any sulphides present may be volatilized by aeration or destroyed by oxidation upon contact with the oxygen.

Any samples, not preserved with zinc acetate, must be analyzed for sulphides within 3 minutes of the time of sampling.

For the on-the-spot tests, small test kits utilizing colorimetric methods are available. These provide reasonably good analyses for low concentrations of hydrogen sulphide.

## SUMMARY

The general methods for the removal of hydrogen sulphide in water supplies may involve one or a combination of the following treatment practices:

(a) aeration
(b) aeration with pH adjustment
(c) chemical treatment with chlorination
(d) ion exchange with strongly basic anion resins

The method selected for a particular water supply will be determined by various factors such as:

(a) total sulphide
(b) chemical quality of the raw water
(c) ultimate use of the water
(d) desired level of sulphide in the treated water
(e) availability of treatment facilities

It should be remembered that these methods of treatment will only remove or reduce sulphides to acceptable levels. In some instances, further treatment involving coagulation and filtration may be required to produce water of good clarity and acceptable quality.

The importance of good disinfection practices cannot be overemphasized in helping to minimize the nuisance problems experienced in water supplies affected by hydrogen sulphide.

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# METHODS OF SOFTENING AND IRON REMOVAL

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The hardness in water as well as iron and manganese can be removed either by treatment, which changes the soluble minerals to insoluble compounds and removes these insolubles by settling and filtration, or by an exchange process which exchanges or trades the hardening elements calcium and magnesium, as well as dissolved iron and manganese for a less objectionable element, generally sodium. These elements, calcium, magnesium, iron and magnesium are found in rocks and are dissolved into the water by chemical reactions with the biproducts of bacteriological activity. Bacteria produce carbon dioxide which dissolves in the water and then reacts with limestone or gypsum to produce soluble calcium and magnesium salt in the water. Siderite, which is ferrous bicarbonate, is one of the principal sources of iron as it is soluble in its own right and this solubility is substantially increased by the presence of carbon dioxide in the water.

## SOFTENING PROCESSES

Since the methods used to remove hardness are equally applicable to the removal of iron, we will begin with the softening processes.

The first of these softening processes is called lime softening or lime-soda softening, depending on the characteristics of the raw water and the chemicals used in the softening processes. The following list of equations give all the chemical reactions of both processes:-

a. $Ca(HCO_3)_2 + Ca(OH)_2 = 2\ CaCO_3 + 2H_2O$

b. $Mg(HCO_3)_2 + Ca(OH)_2 = MgCO_3 + CaCO_3 + 2H_2O$

c. $MgCO_3 + 2Ca(OH)_2 = Mg(OH)_2 + CaCO_3 + \text{Excess } Ca(OH)_2$

d. $MgSO_4 + 2\ Ca(OH)_2 = Mg(OH)_2 + CaSO_4 + \text{Excess } Ca(OH)_2$

e. $CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$

f. $MgCl_2 + Ca(OH)_2 = Mg(OH)_2 + CaCl_2$

g. $CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaNO_3$

h. $C+O_2 = CO_2$ (from coke or natural gas etc.)

i. $CO_2 + Ca(OH)_2 = CaCO_3 + H_2O$

j. $2CO_2 + CaCO_3 = Ca(HCO_3)_2$

k. $CO_2 + Mg(OH)_2 = MgCO_3 + H_2O$

Since most people on this course are not chemists, we will not discuss these equations in detail but rather will deal with the principle of operation. The lime and lime-soda process depend on the insolubility of calcium carbonate and magnesium hydroxide. Lime applied to the water produces these relatively insoluble products and reduces calcium bicarbonate and magnesium bicarbonate content of the water as shown in reactions a and b. If sone of the hardness in the water is present as sulphates or chlorides, the soda must be added to convert these to the same insoluble salts as indicated in equations e, g and i.

The reactions can be carried out in a conventional sedimentation basin which has been altered to provide sludge recirculation and removal, but greater chemical efficiency is provided in an upflow type clarifier preferably of the sludge recirculating type.

Since the addition of lime raises the pH of the water, this system provides excellent iron removal and at pH 9.0 to 9.6 complete removal is assured. Manganese removal is accomplished in the same pH range.

The other chemical additive required is a coagulant.

a. $Ca(HCO_3)_2 + Ca(OH)_2 = 2\ CaCO_3 + 2H_2O$

b. $Mg(HCO_3)_2 + Ca(OH)_2 = MgCO_3 + CaCO_3 + 2H_2O$

c. $MgCO_3 + 2Ca(OH)_2 = Mg(OH)_2 + CaCO_3 + \text{Excess } Ca(OH)_2$

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Since the addition of lime raises the pH of the water, this system provides excellent iron removal and at pH 9.0 to 9.6 complete removal is assured. Manganese removal is accomplished in the same pH range.

The other chemical additive required is a coagulant.

Either alum or one of the iron salts are used. Without these the particles of precipitate will not settle fast enough to remove them during the sedimentation period.

The minimum hardness which can be obtained by this process is 35-40 ppm. In practice however, higher residual hardnesses are maintained generally in the 80 to 150 ppm range. It is the calcium carbonate in the water which provides the corrosion protection in the distribution system. The levels indicated are sufficient to leave enough calcium for the protection of the distribution system. In many cases the plant effluent must be treated with carbon dioxide to convert the calcium carbonate to the soluble bicarbonate. Without this treatment the overly insoluble carbonate would precipitate in the filters and the distribution system far in excess of the requirements of main protection.

The second, and in Ontario, more common treatment system is the ion exchange or zeolite process. In this process the water to be treated is passed through a bed of ion exchange resin where the hardening elements calcium and magnesium are exchanged or traded for the non-hardening element, sodium. Since the exchange can be made equally well between iron or manganese and sodium, the process is also used as an iron removal process. Once the exchange capacity of the material has been exhausted, it can be rejuvenated by passing a solution of any sodium salt such as common salt NaCl, through the bed. This will force the sodium back on to the exchanger and at the same time, the exchanger will release the calcium and magnesium which is discharged to the drain. Once the excess salt has been rinsed to drain, and fresh water once again obtained, the exchanger can soften another batch of water.

When the exchanger is used for iron removal, care must be taken to ensure that the iron reaches the exchange in the dissolved state. Any precipitated iron will be removed as a solid by the filtering action of the zeolite. The precipitated iron will coat the zeolite and this coating will prevent the salt from contacting the zeolite and no regeneration of the zeolite can take place. As the iron builds up in the bed, the capacity of the zeolite bed to soften, decreases. If allowed to go unchecked, the capacity can fall to zero. Periodic treatment with muriatic acid will generally restore the capacity dissolving the ion.

Softeners will only function satisfactorily on a clear, clean water supply. Suspended matter will foul the zeolite in the same manner as iron and therefore, dirty water supplies must be treated prior to softening. Treatment would include filtration and if necessary coagulation and sedimentation.

Corrosion of the iron piping in the distribution system is a source of iron to be considered. This problem can only be overcome by changing the chemical properties of the water, i.e. by chemical treatment. You can either change the characteristics of the water, i.e. raise the pH with lime or soda ash, or put protective film on the interior of the pipe, i.e. sodium hexametaphosphate is sometimes used. A determination of the Langelier Index will be indicative of the tendency of the water to be either corrosive or scale forming. A further test in which you leave a sample of water overnight in contact with calcite crystals ( crystal form of limestone ) is helpful. If the hardness has increased, the water is corrosive; if it has decreased, it is scale forming. If the water is corrosive the change in hardness can be used to calculate the correct chemical dosage required to overcome the problem. In most cases, increasing the pH 8.2 to 8.4 will prove satisfactory.

## ANTISETTLING CHEMICALS FOR IRON

When iron is present in small quantities, i.e. less than 0.5 ppm, it is sometimes practical to limit the problem which it causes by adding a chemical to keep it from settling out in the water mains. 0.3 ppm of iron in the raw water may not be a problem if the maximum concentration can be limited to that figure. Unfortunately with most untreated systems the iron precipitates out and accumulates in the water main. A surge of flow picks up the accumulated iron delivering it to the consumers in high dosages of short duration or as rust particles. Both sodium silicate and sodium hexametaphosphate have been used effectively to hold iron in suspension for varying lengths of time. Normal feed of phosphate is 2-3 ppm per part of iron and minimum dosage 2 ppm of phosphate. The phosphate must be fed prior to any chlorination. Since the action of the phosphate is to keep the ultra fine particles of precipitated iron from agglomerating and precipitating, chlorination does not affect process if applied after allowing a 10-minute reaction time with the phosphate.

Silicates were not as commonly used as antiprecipitants, however more recent data indicates that they have many superior properties. Unlike the phosphate they operate best when applied immediately after chlorination. The dosage applied is 5 ppm as $SiO_2$ or 20 ppm in terms of N brand sodium silicate.

REMOVAL METHODS FOR IRON

To date, no specific test or group of tests have been developed which will foretell the best method of iron removal treatment for a given water supply. Our experience and that of some others has shown that there are some characteristics which point out those supplies which might prove difficult to treat, i.e. a bicarbonate water with no sulphate - and with ammonia - a bicarbonate water is one in which the bicarbonate alkalinity is equal or greater than the total hardness, also a low redox potential after aeration - some say less than 240 of our tests indicate a value of about 140 is critical. Out of some 13 supplies tested for iron removal over the past year, only three proved to be untreatable by aeration or chlorination with filtration and in each of the cases the water had the above two characteristics. The presence of silica in excess of 20 ppm $SiO_2$ can be a serious deterrent to the filtration process.

The methods of removing iron can be classified as follows: - aeration or chlorination and filtration, oxidation units, ion exchange; aeration with coagulation, diatomaceous earth filtration with chemical feed.

AERATION

The basic equation for the oxidation of iron can be written:

$$4\,Fe(HCO_3)_2 + O_2 + 2H_2O = 4Fe(OH)_3 + 8CO_2$$

on this basis 1 ppm of iron requires 0.14 ppm of oxygen to convert from the ferrous to the ferric state. The oxidation product is generally written as $Fe(OH)_3$ but should be actually written as $Fe_2O_3 \cdot 3H_2O$ the hydrated oxide. This reaction proceeds best at a pH of above 8.0 and therefore, aeration

serves a dual purpose in that it provides for removal of $CO_2$ which will raise the pH. There are several types of aerators available. The coke tray type with natural ventilation are the least expensive and least efficient. They are only suitable for use with $CO_2$ contents of up to 30 ppm. The more efficient types of aerators are generally called degasifiers as this is their prime design function and aeration is carried out in the process. The water is fed in at the top and air is forced in at the bottom. In some designs a spray head is used; in others slats are installed to break up the falling stream of water. In all types a collecting basin is provided at the base and the water pump to the process from this point. This tank can be sized to provide some retention time of the aerated water.

Pressure aeration can be used to provide oxygen on waters in which little $CO_2$ is present and removal would not be of too great interest as little or no change in pH could be effected. Generally, a portion of the stream is saturated with air by means of a compressor and then combined with the main flow.

Since the oxidation of iron is not an instantaneous reaction, some time must normally be provided for it to come to completion. As mentioned above, this can frequently be done by providing storage under the aerator. The minimum required retention time can only be determined by experimentation prior to design.

The precipitated oxide can be removed by filtration. We would suggest an Anthrafilt filter media due to its higher capacity for solids. Surface washers or air wash are strongly recommended as the sticky nature of the hydrated oxide makes it difficult to remove by backwashing alone.

If the iron content is excessively high, a contact filter should be installed ahead of the regular filter. The contact filter is of similar configuration to the regular unit but has a deeper bed, coarser media and operates at about twice the rate of flow. They will reduce the iron to the 0.5 ppm range and with the coarse media will have long runs even with a high iron content. If iron bacteria are present the supply must be prechlorinated to limit bacteria growth in any of the above filters.

OXIDATION UNITS

This unit employs a specially prepared manganese greensand as the filter medium. The manganese greensand is prepared by depositing a coating of the higher oxides of manganese on the greensand grains. In operation, potassium permanganate is fed into the water stream ahead of the filter. The permanganate will oxidize the iron to its insoluble higher oxide $Fe(OH)_3$. The excess permanganate is also oxidized by the greensand to its higher oxides which are insoluble and are then removed by filtration by the greensand. This excess permanganate serves to maintain the manganese coating on the greensand grains during this process. The chemical equation is as follows:-

$$3Fe(HCO_3)_2 + KMnO_4 + 2H_2O = 3Fe(OH)_3 + MNO_2 + 5CO_2 + KHCO_3$$

The grain size of the manganese greensand is much finer than ordinary filter media and therefore, the head loss builds up much more rapidly and it is customary to provide a layer of anthrafilt over the greensand to remove the bulk of the iron and provide a reasonable run time. We have found the effluent quality to always be at least as good as from an anthrafilt filter, and in most cases much better. Also, since the permanganate effectively controls the iron bacteria, prechlorination is not required.

ION EXCHANGE

While ion exchange will readily remove iron, we would only suggest it where the prime function is softening. Ion exchange is only suitable for iron removal up to a level of about 0.3 ppm. For the exchanger to operate, the iron must be in solution and therefore, great care must be taken to keep the raw water free of oxygen. If iron bacteria are present in the supply, great care must be exercised in the chlorination as any excess of chlorine will accelerate the oxidation not only of the iron, but also of most of the ion exchange resins themselves.

## COAGULATION AND SOFTENING

Where softening of the supply or where the iron is tightly held in solution as chelated iron, coagulation can be attractive. The water should first be aerated and then fed through some type of coagulation or treatment unit as described in the softening section. The clarified water is then filtered through standard sand or anthrafilt filters. Since most of the iron is settled out in the coagulation basin, good filter runs are obtained.

## DIATOMACEOUS EARTH FILTRATION

D. E. filtration has proved to be an effective means of iron removal. The crux of this process seems to lie in precipitating the hydrated iron oxide in the most filterable form. If a strong chemical oxidant is used, the iron precipitates as $Fe_2O_3 \cdot 3H_2O$ which has a gelatenous, flocculent appearance, and will cause a very rapid increase in head loss through the filter. If however, a mild base such as soda ash is used, good runs can be obtained. The water should first be aerated to remove $CO_2$ and reduce chemical dosages. The soda ash and the D. E. body feed are then fed into the stream with a 10-minute retention prior to filtration.

Even better results can be obtained when light burned MgO is used in place of the soda ash. Our experience was similar to that of G. J. Coogan (3) and also of G. R. Bell (4) whose data appeared in the AWWA Journal. Iron concentration in the effluent were trace level only and runs of 20 hours were obtained. There was a slight increase in magnesium in the treated water. MgO dosages ranged from 5 to 20 ppm per ppm of iron and body feed in the range 10 to 20 ppm per ppm iron.

## SUMMARY

We have yet to discover a laboratory test procedure from which we can determine the best method of iron treatment. Iron precipitation tests do provide a reasonable indication particularly when combined with the water analysis data. Each of the processes outlined above have a place in the treatment spectrum and frequently the final decision is influenced by factors other than iron removal i.e. municipal softening.

There is no doubt that for readily treated waters, aeration and filtration will provide the most simple and economical treatment.

The choice in softening process again, is generally dictated by outside factors. In municipalities which pump direct from well to overhead storage, the ion exchange process is most attractive. If however, there is also excess iron or there is ample growth of iron bacteria in the water, then this process cannot be used. Surface water supplies on the other hand, are generally lime softened as they must provide sedimentation tanks to settle of turbidity.

# CHEMICAL FEED PUMPS

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There are many types of chemical feed pumps available to the water treatment plant operator. The common piston pump is sometimes used but is best suited to water pumping. It is too expensive when made of suitable chemical resistant materials and is also difficult to maintain.

The plunger pump is normally used on chemical feed particularly where a high pressure or a high degree of accuracy is required.

For normal water pressures the most suitable pump is the diaphragm type. It is available in a wide range of materials which are suitable for most chemical feed applications, and also in an assortment of diaphragm diameters and types. The diaphragm pump is supplied with single, dual or triple pumping heads. In the last two types, they are usually alternate feed.

Drawing #1 illustrates a fairly standard type of pumphead arrangement. Power is supplied by a small electric motor geared to a crank and pushrod. The rod is not directly connected to the pump diaphragm but, rather, is only used to push out the diaphragm during the pumping stroke. During the suction stroke the diaphragm is drawn in by a spring. The chemical dosage is controlled by limiting the distance the spring can push back the diaphragm. Generally a small eccentric is used to limit the travel of the spring and through it the diaphragm. With the eccentric in its fully opened position the stroke is 100 percent and the pushrod is always in contact with the return spring. At any stroke setting less than 100 percent, the spring and consequently the diaphragm will follow the pushrod on the suction stroke until the spring comes up against the eccentric, and it will stop at that point. The pushrod, however, will continue its suction stroke travel with the crank and then start moving forward on its pressure stroke. Again depending on the setting of the eccentric, it will contact the spring and diaphragm and start them moving forward on the pressure stroke.

The most common diaphragm material is "hyplon" which is a flexible plastic material that has extreme chemical resistance.

The check valves are of various materials and made in a variety of shapes. The most common type is the poppet valve, which is shaped like a mushroom and made of a chemical resistant plastic such as "Koroseal" (a plasticized form of PVC). The stem of the mushroom runs inside the connecting passage of the discharge fitting, as shown in drawing #1, and has fluted sides to allow the chemical to pass by it. The cap of the mushroom acts as a check valve and seals on the top of the passage in the discharge fitting.

The poppet valve is used on liquids of water-like viscosity, and specific gravity which will not attack the plastic. Because of its superior sealing properties as a check valve, it is preferable to the ball type. Where higher viscosities and specific gravities are encountered, the glass ball check is used due to its greater weight. If even more weight is required, a stainless steel ball is used. Glass ball checks are usually used for active chemicals such as potassium permanganate. They are not suitable for fluorides as they attack glass.

Where the feed pump discharges into a pipe with negative head, such as a pump suction, or discharges at a level below the pump, it is necessary to provide an antisyphon valve in the pump discharge. The antisyphon valve is shown in drawing #2. The valve is generally mounted directly on the pump body in place of the normal discharge fitting and, consequently, contains the discharge check valve. The spring loading on the diaphragm provides a normal load of 10 psi. In operation, the pressure of the liquid in the pump discharge opens the valve by the pressure at "A". The liquid passes over the seat into passage "B" which is an annular ring completely surrounding inlet "A". A discharge port "C" with a boss for the discharge hose is provided. If a suction is provided at point "C", it will draw down the diaphragm against the seat but will not withdraw any chemical. The pump pressure is more than enough to open the diaphragm when pumping.

Where it is necessary to feed more than one chemical at one location, a multiple head feeder can be used. It must be remembered, however, that if the single motor fails there will be no chemicals fed. From the point of view of control, it is more convenient to feed only one chemical through one pumphead, as the feed rate of the individual chemicals can be varied independently of each other. In an emergency, however, many chemicals can be mixed and fed through a single pump -- hypochlorite and lime are sometimes fed together. The point here is that with single head feeders on a multichemical feed operation, the loss of one feed pump does not always prevent the feeding of all chemicals.

The standard diaphragm pump is suitable for use only where the rate of flow is constant. In locations where the water flow rate varies, it is necessary to vary the chemical feed rate in order to maintain a constant dosage. A water meter or some other similar metering device must be installed to measure the flow and put out a suitable signal to control the pump. This can be an air pressure signal operating at a 3 to 15 p.s.i. range, where 3 p.s.i. equals zero flow and 15 p.s.i. equals 100 percent of flow, or it can be a pulse duration signal. A common type gives a 4-second pulse at zero flow and a 26-second pulse at full flow, so that the feeder would operate once every 30 seconds and would run for a number of seconds between these two values, depending on the water flow rate. In some cases, a variable speed drive is used and the output speed of the motor is controlled according to the water flow rate. The control could be either the air signal or pulse duration. The control can either vary the stroke length proportional to flow or vary the ON time of the motor proportional to flow. The first method is more preferable. Since the strokes per minute do not change, it will not materially alter the time between chemical additions. Where the ON time of the motor is varied (pulse duration), the number of times chemical is added per minute can become extremely low.

Even in some constant speed applications the stroking speed must be considered. If your pump is one in which the pumphead and motor are separate with cone pulleys and a V-belt, always operate at a high stroking speed. You must use low stroke length even though it does increase the pump wear, but it will provide the optimum and most even application of chemical. If you

are concerned about the time between pulse of chemical, you should consider a dual headed feeder. Most of these feed, alternately, through the heads rather than simultaneously and a much more even feed is obtained.

In some installations there is a problem of mixing the feed chemicals and the water in a pipeline. This can be overcome through the use of an inline motor-driven, mechanical mixer, or with inline mixing chambers utilizing a chemical packing such as "Berl Saddles" or "Raschig Rings".

At least one manufacturer provides a water-driven, chemical feed pump, paced by a water meter, which is flow proportional and feeds the chemical more than 50 percent of the time. The feed pump is driven with a water pressurized diaphragm in which the water is allowed to slowly enter during the power stroke, but is vented rapidly on the spring-returned, suction stroke. This does serve to provide chemical feed for a larger percentage of the time.

When chemical feed pumps are used on slurries such as lime, diatomaceous earth or carbon, they must be equipped with flushing lines as the slurry will otherwise settle out and accumulate in the pump and piping. The clean flushing water must be introduced on the suction side of the pump to clean both sets of check valves, as well as the diaphragm chamber and the discharge line. Most manufacturers supply pumps with optional flushing connections on the suction valves and include with them the necessary automatic timers and valves to control the flushing operation.

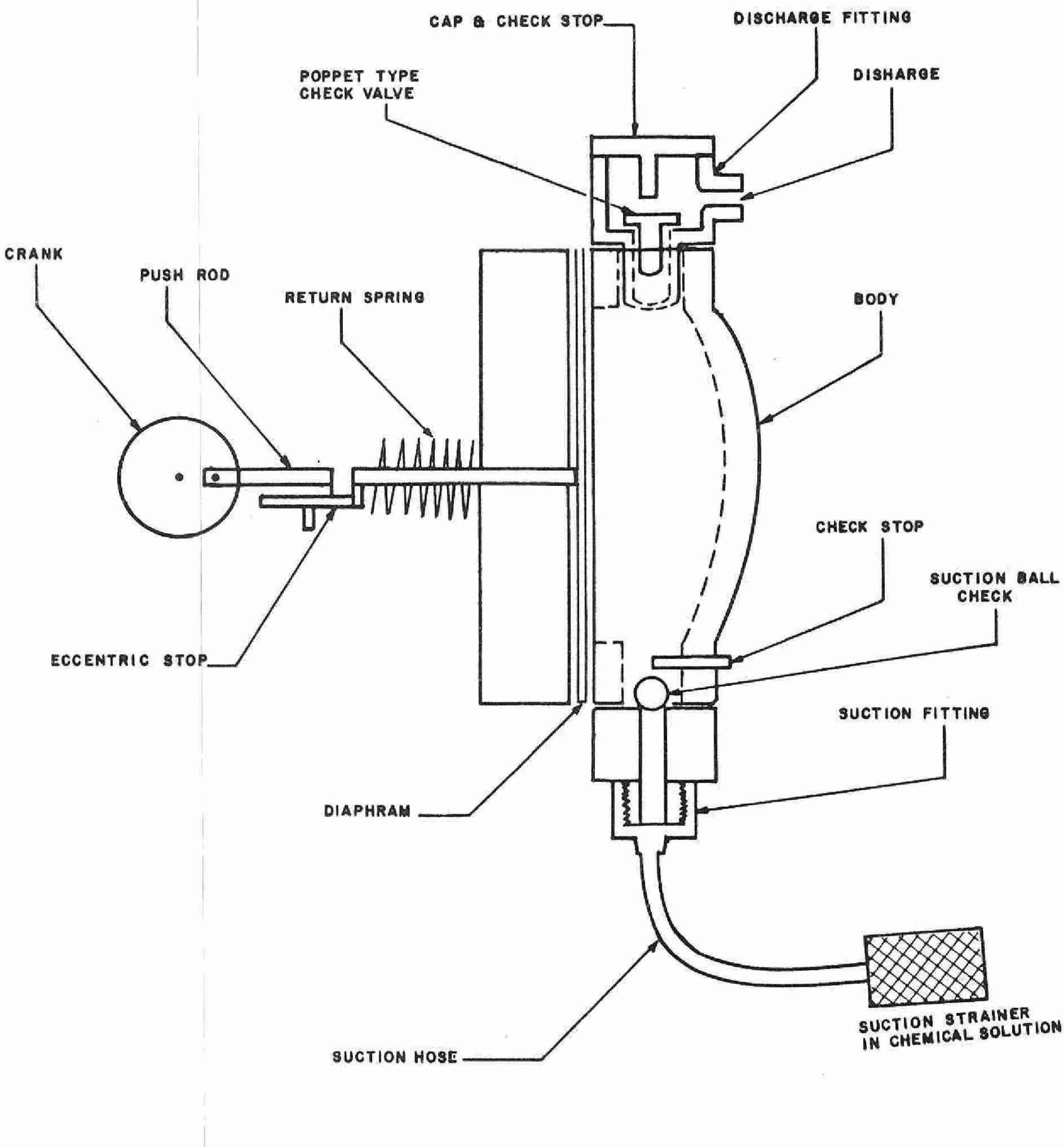
Where two chemicals such as lime and hypochlorite are being fed, a dual headed pump can be utilized and the chlorine pumped through the lime head to provide flushing. It must be remembered, however, that this procedure will reduce the output capacity of each of the heads to 50 percent of their rated capacity.

Where the pump is used on hypochlorite solution, a white scale of calcium carbonate will build up on the inside of the pumphead and on the check valves and tubing. A mild solution of muriatic acid(mix 2 volumes of water with one of acid) will normally remove the scale. The general procedure is to pump the acid through the pump to waste, then rinse with sodium bicarbonate to neutralize the acid.

When a more accurate control of the chemical flow is required, or where a high pressure is encountered, a plunger pump is generally used. Drawing #3 illustrates this type of pumphead. For most chemical applications, a ceramic plunger is utilized with a stainless steel or hastalloy cylinder. Unlike the diaphragm pump, the plunger in this pump is attached directly to the connecting rod and moves with it on both suction and pressure strokes. A more sophisticated method of stroke adjustment such as the "Scotch Yolk" is utilized and proportional feed is attained by automatic stroke control, variable speed drives, or by interrupting the power supply to the motor as outlined for diaphragm pump control. With a standard 110 or 220 volt single-phase motor, no more than 4 start-stops per minute can be tolerated without burning out the starting winding of the motor.

DWG. No: I

## DIAPHRAM PUMP



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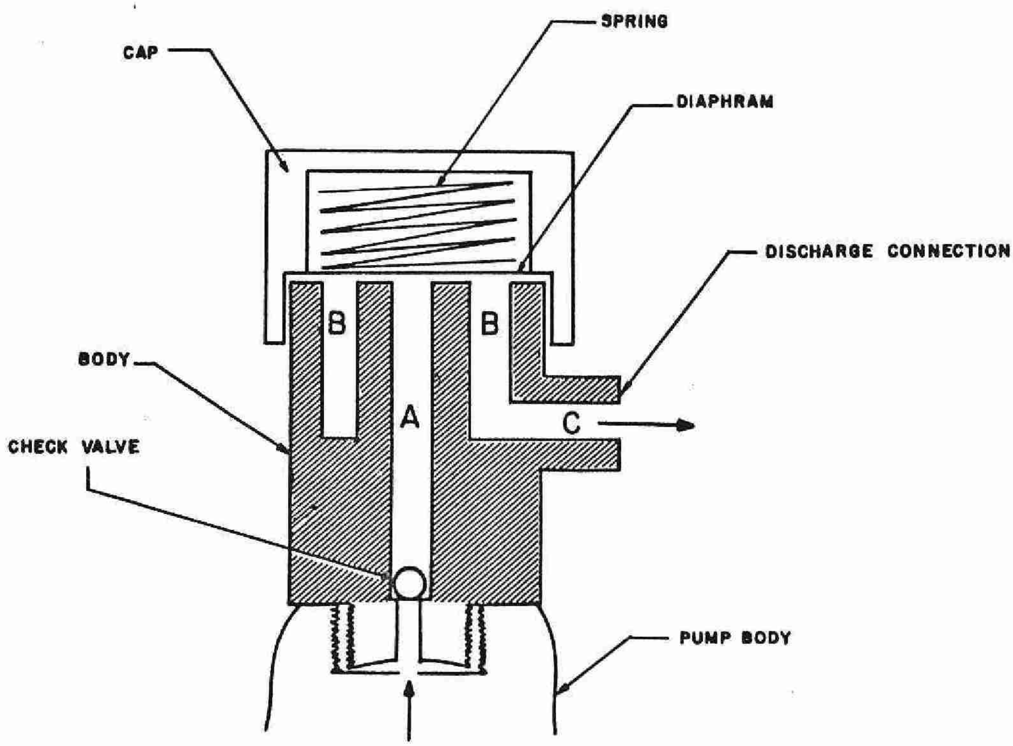
## ANTI SYPHON VALVE

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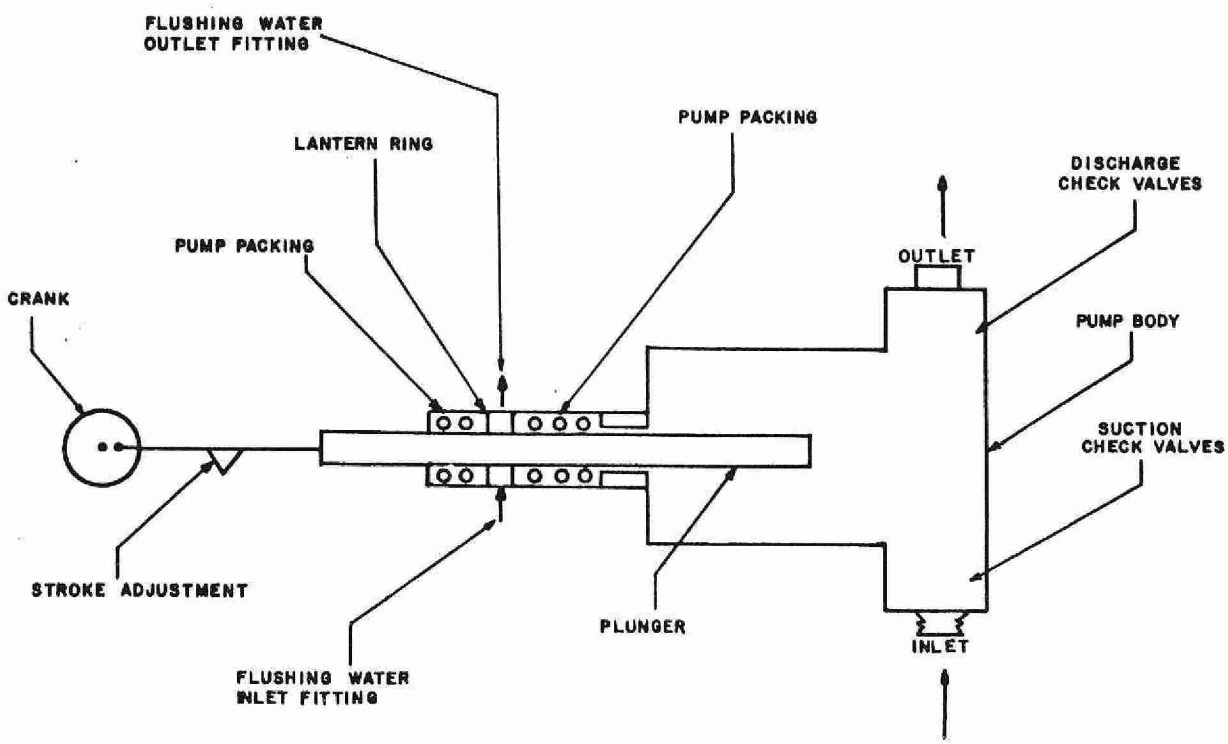
## PLUNGER TYPE PUMP



# PART III

# G E N E R A L

# MATHEMATICS

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This discussion is concerned with basic mathematics. Before one can solve the problems related to dosages, pumpages, flow rates etc., he must be able to understand certain fundamental mathematics. This discussion will deal briefly with simple mathematics and with certain rules and concepts, which if used will make mathematics easier to understand and to perform. A number of problems along with their solutions, are included to illustrate these rules and concepts.

Mathematics is the science of calculation of quantities and is used to describe as a group the three basic sciences - arithmetic, algebra and geometry.

Arithmetic is the study of numbers and the use of numbers to count, describe and calculate quantities. It includes the simple mechanical process of addition, subtraction, multiplication and division.

Geometry is the study of the magnitudes of space, such as lines, surfaces and planes.

Algebra uses symbols and equations to describe the relation between quantities and to determine solutions to problems.

## ARITHMETIC

Arithmetic will be discussed under the following headings:

addition
subtraction
multiplication
division
fractions
decimals
percent

## Addition

Probably the only rule to remember in adding numbers which do not have the same number of digits is to line them up starting from the right-hand side.

The symbol for adding is +

Example:

Add 6,404; 28; 732

$$\begin{array}{r} 6{,}404 \\ 28 \\ \underline{732} \\ 7{,}164 \end{array}$$

## Subtraction

The same basic rules which apply to addition apply to subtraction.

The symbol for subtraction is -

Example:

Subtract 828 from 4,272

$$\begin{array}{r} 4{,}272 \\ \underline{-\ 828} \\ 3{,}444 \end{array}$$

## Multiplication

Multiplication is the process of repeating or adding a given number a certain number of times. The number which is being multiplied is called the multiplicand; the number by which it is multiplied is called the multiplier; and the result is termed the product.

The symbol for multiplication is x

<u>Example</u>:

Multiply 6,785 by 14

```
 6,785   (multiplicand)
  x 14   (multiplier)
 -----
 27140
 6785
 -----
 94990   (product)
```

<u>Division</u>

Division is simply the process of finding how many times one number or quantity is contained in another. The number which is being divided is called the dividend; the number which it is divided by is called the divisor; and the resultant number is the quotient. Quite often there is also a remainder.

The symbol for division is ÷

<u>Example</u>:

Divide 1,752 by 12

```
     146
 12/1752
    12xx
    --
     55
     48
     --
      72
      72
      --
       0 - no remainder
```

Divide 18,473 by 68

```
               271   (quotient)
 (divisor) 68/18473  (dividend)
              136xx
              ---
               487
               476
               ---
                113
                 68
                ---
                 45  (remainder)
```

## Fractions

In many cases it is impossible to express a quantity as a whole number, and we must use fractional numbers such as 1/8, 1/4, 2/3 etc. Difficulty is often experienced in doing minor calculations with fractions. A brief review of the calculations involved in the addition, subtraction, multiplication and division of fractions is presented.

The upper number in a fraction is called the numerator, the lower is called the denominator.

### (1) Adding Fractions

Before fractions may be added they must all have a common denominator. To get a common denominator, find the smallest number into which all of the denominators will divide. Having obtained this number, multiply the numerator and denominator of each fraction by the number of times its denominator divides into the common denominator.

Fractions should always be reduced to their simplest form.

Example:

Add $\frac{3}{8}$, $\frac{1}{4}$ and $\frac{5}{16}$

By inspection the lowest number into which each of the denominators will divide is 16, and this is the common denominator. Now 8 will divide into 16 twice, and multiplying the numerator and denominator by 2, the fraction now becomes 6/16. Similarly, 1/4 becomes 4/16 and we can now add because they all have a common denominator.

$$\frac{6}{16} + \frac{4}{16} + \frac{5}{16} = \frac{15}{16}$$

Often a whole number will contain a fraction, and before calculations may be made the number should be changed to a fraction only.

<u>Example</u>:

Add $\frac{1}{8}$ and $5\ \frac{3}{4}$

The number 5 3/4 is changed to a fraction by multiplying the denominator by the whole-number portion and adding the numerator, that is, 4 times 5 plus 3, and the number becomes 23/4.

We now have:

$$\frac{1}{8} + \frac{23}{4}$$

Changing to a common denominator of 8:

$$\frac{1}{8} + \frac{46}{8} = \frac{47}{8} \text{ or } 5\ \frac{7}{8}$$

(2) <u>Subtracting Fractions</u>

The rules for subtracting fractions are similar to those for adding - there must be a common denominator.

<u>Example</u>:

Subtract $\frac{3}{16}$ from $\frac{8}{32}$

$$\frac{8}{32} - \frac{3}{16}$$

$$= \frac{8}{32} - \frac{6}{32} = \frac{2}{32} \text{ or } \frac{1}{16}$$

(3) <u>Multiplying Fractions</u>

It is not necessary to change simple fractions to a common denominator before multiplying. Simply miltiply the two numerators and the two denominators together.

<u>Example</u>:

Multiply $\frac{3}{4}$ by $\frac{2}{3}$

$$\frac{3}{4} \times \frac{2}{3}$$

$$= \frac{3 \times 2}{4 \times 3} = \frac{6}{12} \text{ or } \frac{1}{2}$$

When one of the numbers to be multiplied contains a whole number and a fraction it must be changed to a simple fraction before multiplying.

<u>Example</u>:

Multiply $\frac{1}{4}$ by $3\ \frac{5}{8}$

$$\frac{1}{4} \times 3\ \frac{5}{8}$$

$$= \frac{1}{4} \times \frac{29}{8}$$

$$= \frac{1}{4} \times \frac{29}{8} = \frac{29}{32}$$

(4) <u>Dividing Fractions</u>

To divide one fraction by another the simplest rule to follow is to invert the bottom fraction and multiply.

<u>Example</u>:

Divide $\frac{5}{16}$ by $\frac{3}{4}$

$$= \frac{5}{16} \div \frac{3}{4}$$

$$= \frac{5/16}{3/4}$$

$$= \frac{5}{16} \times \frac{4}{3}$$

$$= \frac{5 \times 4}{16 \times 3} = \frac{20}{48} = \frac{5}{12}$$

Example:

Divide $5\frac{3}{4}$ by $\frac{1}{8}$

$$5\frac{3}{4} \div \frac{1}{8}$$

$$= \frac{5\ 3/4}{1/8}$$

$$= \frac{23/4}{1/8}$$

$$= \frac{23}{4} \times \frac{8}{1}$$

$$= \frac{184}{4} = \frac{46}{1} = 46$$

Decimals

Another method of expressing fractional numbers is by the use of decimals. Decimals express fractions in multiples of 10, that is, tenths, hundredths and thousandths.

$$\frac{1}{10} = 0.1 \qquad \frac{1}{100} = 0.01 \qquad \frac{1}{1000} = 0.001$$

As shown above, a decimal fraction is denoted by a digit with a period in front of it. The value of the decimal depends on the position of the figures with respect to the decimal point. For example, if a decimal is immediately in front of a number it means that the number has been divided by 10.

Example:

$$0.7 = \frac{7}{10}$$

If there is a zero between the number and the decimal it means that the number has been divided by 100.

Example:

$$0.09 = \frac{9}{100}$$

In addition to decimal fractions there are also mixed decimals which are whole numbers with a decimal fraction.

Example:

$$12\frac{1}{2} = 12.5$$

(1) Adding Decimals

When adding decimals the numbers must be listed one below the other with the decimal points in a vertical line.

Example:

Add 31.56, 4.32 and 88.8

$$\begin{array}{r} 31.56 \\ 4.32 \\ \underline{88.80} \\ 124.68 \end{array}$$

(2) Subtracting Decimals

The rules for subtracting decimals are similar to those for adding.

Example:

Subtract 8.4 from 14.73

$$\begin{array}{r} 14.73 \\ \underline{-\ 8.40} \\ 6.33 \end{array}$$

Example:

Subtract 9.32 from 17.8

$$\begin{array}{r} 17.80 \\ \underline{-\ 9.32} \\ 8.48 \end{array}$$

(3) Multiplying Decimals

This is done in the same way as ordinary multiplying and the decimal point is disregarded during the calculation. Add the total number of digits to the right of the decimal in the two numbers being multiplied and insert the decimal point in the answer.

Example:

Multiply 3.55 by 3.2

```
  3.55
   3.2
  ----
   710
 1065
 -----
 11360 or 11.360
```

Since there are a total of three digits to the right of the decimal in the two numbers multiplied, there must be three digits to the right of the decimal in the answer.

(4) Dividing Decimals

Before dividing numbers which contain decimals the decimal in the divisor should be moved a sufficient number of digits to the right to change it to a whole number. Of course, the decimal in the dividend must also be moved a similar number of digits to the right.

Example:

Divide 253.5104 by 3.52

3.52/253.5104 becomes

```
        72.02
 352/25351.04
     2464
     ----
      711
      704
      -----
        704
        704
        ---
          0
```

The decimal point in the answer (quotient) is placed directly above the decimal point in the dividend.

To change a fraction to a decimal simply divide the numerator by the denominator.

Example:

Change 1/4 to a decimal

$$
\begin{array}{r}
0.25 \\
4\overline{)1.00} \\
\underline{8\phantom{0}} \\
20 \\
\underline{20} \\
0
\end{array}
$$

Therefore 1/4 = 0.25

## Percent

Percent is a proportion expressed in hundredths and is used to provide a comparison of the whole. For example, one percent represents 1/100 part of the whole.

Example:

A student obtains 75 marks on a test out of a total of 100. What was his percent?

$$\frac{75}{100} \times 100 = 75 \text{ percent}$$

# ALGEBRA

Although the water works operator will not be called upon too often to use algebra, a little understanding of the subject will be helpful.

## Equations

The most commonly encountered item in algebra is the equation, which is simply a statement of equality of two quantities.

Examples:

$$\begin{aligned} 2 + 2 &= 4 \\ 7 - 4 &= 3 \\ a + b &= c \\ 2x &= 10 \text{ etc.} \end{aligned}$$

As long as the same changes are made to both sides of the equation it will remain unchanged. That is, any amount may be added to or subtracted from both sides, or both sides may be multiplied or divided by the same number, and the equation will remain the same.

Example:

If 3a equals 24, what does a equal?

$$3a = 24$$

Dividing both sides of the equation by 3

$$\frac{3a}{3} = \frac{24}{3}$$

$$a = 8$$

Example:

If $\frac{b}{5} = 3$, what does b equal?

$$5 \times \frac{b}{5} = 3 \times 5$$

$$b = 15$$

## Ratio and Proportion

A ratio is a comparison. For example, if one car costs $6,000 and a second car costs $2,000, we say that the first car is 3 times as expensive as the second. Expressed mathematically the ratio is 3:1 and the value of the ratio is 3.

A proportion is simply a statement of equality between two ratios. In the case of the two cars the proportion is

$$\frac{6,000}{2,000} = \frac{3}{1} \text{ or } 6,000:2,000 = 3:1$$

In practice, numerous problems are encountered in which one ratio is known and we must find an equal ratio of which only one of the items is known.

Example:

A desk is 6 ft. long and 3 ft. wide. A desk of similar shape is required with one side 8 ft. long. What will the width be?

$$\text{desk one } \frac{L}{W} = \frac{6}{3} = 2$$

$$\text{desk two } \frac{8}{W} = 2$$

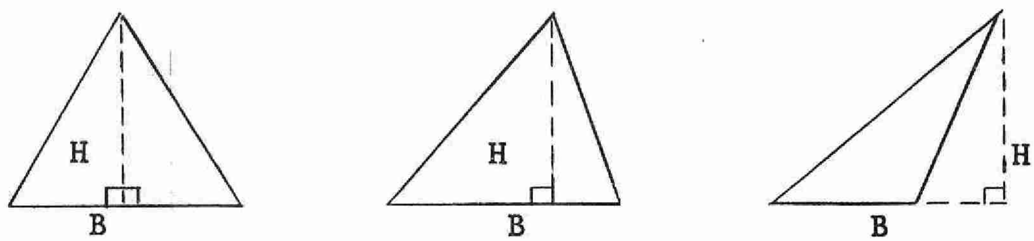
$$\text{Therefore } W = 4$$

GEOMETRY

A water works operator is often called upon to figure out areas and volumes. The types of figures which he is most likely to encounter are shown below:

Areas

(1) Triangle

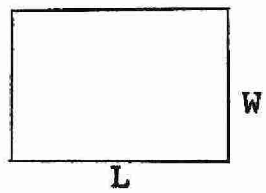



The area of a triangle:

$$A = \frac{1}{2} \text{ base x height}$$

$$= \frac{1}{2} B \times H$$

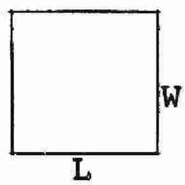
(2) <u>Rectangle</u>




The area of a rectangle:

$$A = L \times W$$

(3) <u>Square</u>

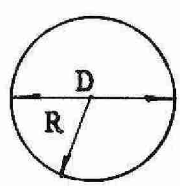



The area of a square:

$$A = L \times W$$
but $L = W$

Therefore $A = L^2$

(4) <u>Circle</u>



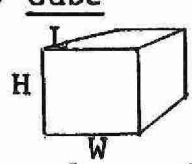

D = diameter
R = radius = 1/2D
C = circumference
$\pi$ = 3.14

The area of a circle:

$$A = \pi R^2 \quad \text{or} \quad \frac{\pi D^2}{4}$$

<u>Volumes</u>

(1) <u>Cube</u>

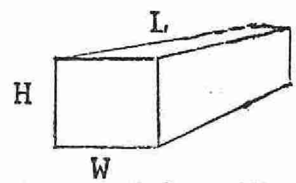



all three sides equal
$L = W = H$

The volume of a cube:

$$V = L \times W \times H = L^3$$

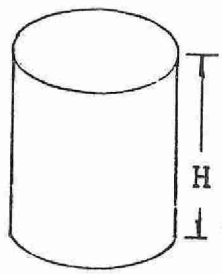
(2) <u>Rectangular Solid</u>




The volume of a rectangular solid:

$$V = L \times W \times H$$

(3) <u>Cylinder</u>




The volume of a cylinder:

$$V = \frac{\pi D^2}{4} \times H$$

## PROBLEMS

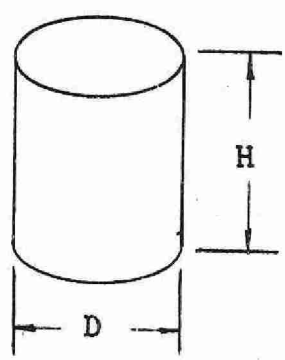
### Example 1

A cylindrical tank 5 feet in diameter is filled with lime slurry to a depth of 11 feet. Assuming it can be drawn down to a level of 1 foot, how many gallons of lime slurry will be drawn off?

Volume of cylinder

$$= \frac{\pi D^2}{4} \times H$$

D = diameter
H = height




$$= \frac{3.14 \times 5^2 \times 10}{4}$$

$$= \frac{3.14 \times 25 \times 10}{4}$$

= 196.2 cubic feet

Since 1 cubic foot = 6.24 gallons, the amount of slurry drawn off

= 196.2 × 6.24

= 1,224 gallons

Example 2

A pump is capable of discharging 400 gallons per minute. What chlorine feed-rate is required to provide a dosage of 2.5 ppm?

400 gpm = 400 x 1,440 x 10 lb. of water per day

Weight of chlorine required

$$= \frac{2.5 \times 400 \times 1{,}440 \times 10}{1{,}000{,}000}$$

= 14.4 lb. per day

Therefore, chlorine feed-rate required is 14.4 lb. per day.

Example 3

A new 12-inch water main 1,000 feet long is to be disinfected with an intended residual of 50 ppm. Assuming a 10-ppm chlorine demand, how many pounds of chlorine gas are needed?

$$\text{Volume of pipe} = \frac{\pi D^2}{4} \times 1{,}000$$

$$= \frac{3.14 \times 1 \times 1{,}000}{4}$$

= 785 cubic feet

Weight of water = 785 x 62.4

= 49,000 lb.

Since there is a chlorine demand of 10 ppm, the dosage must be 60 ppm to provide a residual of 50 ppm.

$$\text{Weight of chlorine} = \frac{60 \times 49{,}000}{1{,}000{,}000}$$

= 2.93 lb.

If calcium hypochlorite, 70 percent available chlorine, were to be used in the above, how many pounds would be required?

Weight of hypochlorite x 0.70 = 2.93 lb.

$$\text{Weight of hypochlorite} = \frac{2.93}{0.70}$$

$$= 4.2 \text{ lb.}$$

Example 4

The recommended dosage of Calgon for the control of "red-water" problems is 2 ppm Calgon for each 1 ppm of iron in the raw water. If the iron content in a water is 1.35 ppm and the average daily consumption is 750,000 gallons, how many pounds of Calgon are required per day?

$$\text{Dosage of Calgon} = 2 \times 1.35$$
$$= 2.70 \text{ ppm}$$

$$\text{Daily requirement} = \frac{2.70 \times 750{,}000 \times 10}{1{,}000{,}000}$$

$$= 20.25 \text{ pounds}$$

Example 5

An aeration device at an iron-removal plant is expected to reduce the iron content of the water from 2.3 ppm down to 0.3. If the average daily flow-rate is 100,000 gallons, how many pounds of iron would be removed?

2 ppm are removed

100,000 gallons = 1,000,000 lb.

$$\text{Therefore,} \quad \frac{2 \times 1{,}000{,}000}{1{,}000{,}000}$$

$$= 2 \text{ lb. are removed}$$

Example 6

The totalizer readings on a meter which times the operation of a pump in hours were 6863 and 6897 at the beginning and end of a pumping period. If the pump is rated at 375 gallons per minute, how many gallons were pumped?

No. of hours of pump operation

$$\begin{array}{r} 6897 \\ -\ \underline{6863} \\ 34 \end{array} \text{ hours}$$

No. of minutes of pumping

$34 \times 60 = 2{,}040$ minutes

Total pumpage

$375 \times 2{,}040 = 765{,}000$ gallons

Example 7

The meter readings at a water works at the beginning and end of a 5-day period were 65,271 and 65,846. If the meter readings represent 1000's of gallons, what was the average daily consumption?

$$\text{Pumpage} = \begin{array}{r} 65{,}846{,}000 \\ -\ \underline{65{,}271{,}000} \\ 575{,}000 \end{array} \text{ gallons}$$

$$\text{Average day} = \frac{575{,}000}{5}$$

$$= 115{,}000 \text{ gallons}$$

If there were 250 homes on the system, and assuming each used the same amount, how much did it cost each home-owner if the water sold at the rate of 41¢ per thousand gallons?

$$\text{Usage per home-owner} = \frac{115{,}000}{250}$$

$$= 460 \text{ gallons}$$

$$\text{Cost} = 0.460 \times 0.41$$
$$= 19¢ \text{ per home-owner}$$

Example 8

If the water level in an elevated storage tank is 165 feet above the adjacent pumphouse pressure gauge, what should the gauge read in pounds per square inch?

1 pound per square inch = 2.31 feet

Therefore, gauge reading $= \frac{165}{2.31}$

$= 71.4$ psi

Example 9

The velocity of the water moving in a 12-inch pipe is 3 feet per second. What is the flow in

(a) cubic feet per second?
(b) gallons per minute?

The flow is equal to the velocity times the area of the pipe

$$Q = VA$$
$$V = 3 \text{ fps}$$
$$A = \frac{\pi D^2}{4} \qquad D = 12 \text{ inches} = 1 \text{ foot}$$
$$= \frac{3.14 \times 1^2}{4}$$
$$= 0.785 \text{ square feet}$$

(a) $Q = 3 \times 0.785$
$= 2.355$ cubic feet per second

(b) $Q = 2.355 \times 375$
$= 883$ gpm

## TABLE I

| BRITISH SYSTEM | METRIC SYSTEM |
|---|---|
| **Linear Measure** | **Linear Measure** |
| 1 foot = 12 inches | 1 centimeter = 10 millimeters |
| 1 yard = 3 feet | 1 meter = 100 centimeters |
| 1 rod = 5 1/2 yards | 1 kilometer = 1,000 meters |
| 1 mile = 1,760 yards | |
| 1 mile = 5,280 feet | |
| **Square Measure** | **Square Measure** |
| 1 square foot = 144 sq. in. | 1 sq. centimeter = 100 sq. mm |
| 1 square yard = 9 sq. ft. | 1 sq. meter = 1000 sq. centimeter |
| 1 acre = 160 sq. rods | 1 sq. kilometer = 1,000,000 sq. meters |
| 1 square mile = 640 acres | |
| 1 acre = 43,560 sq. ft. | |
| **Cubic Measure** | **Cubic Measure** |
| 1 cubic foot = 1,728 cu. in. | 1 cu. centimeter = 1000 cu. mm |
| 1 cubic yard = 27 cu. ft. | 1 cu. meter = 1,000 litres |
| **Weight** | **Metric Weight** |
| 1 pound = 16 ounces | 1 gram = 1,000 milligrams |
| 1 ton = 2,000 pounds | 1 kilogram = 1,000 grams |
| 1 pound = 7,000 grains | |
| **Liquid Measure** | |
| 1 quart = 2 pints | |
| 1 gallon = 4 quarts | |

### CONVERSION FACTORS

| | | |
|---|---|---|
| 1 cubic foot | = | 62.4 pounds |
| 1 cubic foot | = | 6.24 gallons |
| 1 gallon | = | 10 pounds |
| 1 gallon per minute | = | 1,440 gallons per day |
| 1 cubic foot per second | = | 539,000 gallons per day |
| 1 cubic foot per second | = | 375 gallons per minute |
| 1 grain per gallon | = | 14.3 parts per million |
| 1 Imperial gallon | = | 1.2 US gallons |
| 1 US gallon | = | 0.833 Imperial gallons |
| 1 pound per sq. inch | = | 2.31 feet of head |

# BASIC ELECTRICAL TEST AND MAINTENANCE

J. Blair

Technical - Specialist

## INTRODUCTION

You are responsible for the efficient operation of the electrical equipment at your station. This section is intended to acquaint you with the various terms used in electricity, and with the various instruments that ensure satisfactory operation. This should help you determine when a fault exists and what action should be taken to correct the fault.

If you have any doubts about any piece of equipment, or you'd like to have some technical brochures or data, just drop us a line and we will try to obtain the information required. Just write to:

Mr. A. E. Symmonds,
Ontario Water Resources Comm.,
Division of Plant Operations,
135 St. Clair Ave. West.,
Toronto 7, Ontario.

## SAFETY

Never work alone on electrical equipment when it is energized even the most careful person can be careless and if you get caught on 575 volts it is not a situation from which you can easily escape. You at least stand a chance if their is someone else in the room to pull a switch or get you off the line.

Never take it for granted that the line is deenergized when you pull a switch, the switch may be faulty.

In some cases, there is voltage supplied from another source of which you are not aware.

Before doing work on electrical equipment, test for voltage with a voltmeter or a neon tester.

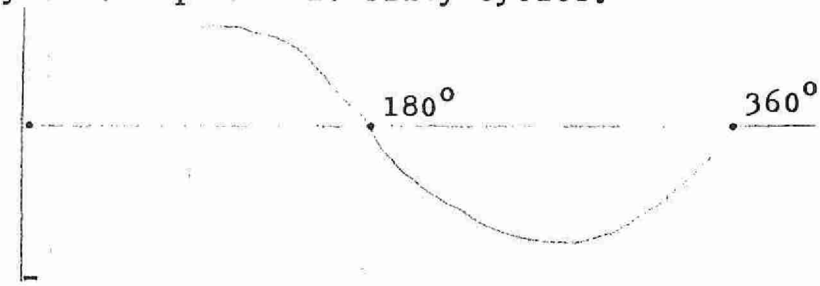
It at times you have to take current or voltage readings, the panel will obviously have to be energized. You must therefore use all safety equipment available to you such as safety gloves, rubber mats and fuse pullers.

ELECTRICAL TERMS AND THEIR MEANINGS

A.C.: An abbreviation for alternating current. This means the current changes direction and magnitude at a certain frequency. The frequency may vary.

FREQUENCY

The number of complete varations or cycles made by alternating current per second. The most common frequency in our plants is sixty cycles.




The illustration above shows one complete cycle showing the current starting at zero and reaching its peak magnitude at 90°. It then decreases to zero, and reaches its peak in the negative direction at 270°. When it decreases to zero at 360°, it is ready to start a complete new cycle.

INSULATION

A material used to prevent the flow of electricity between certain points. Insulators are found in nearly all electrical equipment. They are used on the cables that run to the equipment, on transformers, the motors and switches. Types of insulation material include rubber, oil, mica, paper and plastics.

CIRCUIT BREAKER

An automatic device that opeans a circuit under abnormal conditions. If a short circuit occurs, the breaker will automatically trip and cannot be re-closed until the internal thermal unit has cooled.

## CONTACTOR

A device operated other than by hand for repeatedly establishing and interrupting an electric power circuit. Contactors are used in control as well as power circuits, with load currents on the contacts ranging from fractions of an ampere to thousands of amps.

## AMBIENT TEMPERATURE

The temperature of the air where a piece of equipment is situated. Most controllers are of the enclosed type, and the ambient temperature is the temperature of the air outside the enclosure - not inside. Similarly, if a motor is said to be in an ambient temperature of $40^{o}$c this is the temperature outside the motor and not inside.

## TEMPERATURE RISE

The quality of insulation is often expressed by the allowable temperature rise, and equipment which uses the insulation is classed in the same way. A motor may be insulated with a material having an allowable temperature rise of $40^{o}$c, and would therefore be referred to as a $40^{o}$c rise motor. When the motor is operating at full load, the temperature of the insulation will not be more than $40^{o}$c higher than it was before the motor started. The allowable temperature rise is based on a maximum ambient temperature of $40^{o}$c, the allowable temperature rise must be reduced. For example, if the ambient temperature is $50^{o}$c, the allowable temperature rise must be reduced by $10^{o}$c (50-40.)

## TORQUE

The turning or twisting power of the motor, usually measured in foot pounds.

## MAINTENANCE OF ELECTRICAL EQUIPMENT

1) Why do we have maintenance?
2) What good does it do?
3) Its cheaper to forget it.
4) Wait until it breaks down.

These are some statements we have heard in the field and the controversy continues. Nobody seems to have come up with any definite proof of whether a piece of equipment will last longer un-maintained or not.

At present many industries and insitutions have initiated a preventative maintenance program. This is a method of systematically and regularly checking electrical equipment. These programs are pre-set and the maintenance personnel regularly fill in a check sheet and note any discrepancies. A defect as minor as a loose screw might appear insignificant at the time of inspection but it could cause a short circuit or a major fire.

Electrical equipment is used in nearly all types of environment: outdoors in freezing temperatures operating at boiling point submerged under water or under the ground.

Although some electrical equipment is stationary it can be damaged very easily by adverse operating conditions water, heat, dust, cold, humidity, vibration and many other conditions. To help avoid deterioration in all situations you should follow three simple rules.

1) Keep it clean.
2) Keep it dry.
3) Keep it tight.

Keep it Clean

One of the main causes of equipment failure is dirt. In our plants this usually derives from a day-to-day accumulation of dust, chemicals or lint. This dirt attacks moving parts and makes them sluggish. Electricity could arc over to ground causing burning. Everytime you inspect a piece of equipment ensure it is clean.

Keep it Dry

Electrical equipment is designed to operate in dry conditions. If equipment has to operate in damp or moist conditions, the manufacturers make special enclosures for operation in these situations.

Moisture rusts metallic parts in the equipment causing bad contact, sluggish operation and eventually complete breakdown.

Keep it Tight

Vibration of equipment causes nuts and bolts to loosen, or wires to fray and eventually break off.

A regular check of all bolts is a simple operation, but it saves a lot of time if you had to re-place a complex piece of electrical equipment.

TYPES OF MAINTENANCE

There are three classes of maintenance: Ordinary Maintenance, Repairs and Preventative maintenance.

Repairs

This is where we wait until equipment breaks down. The plant shuts down, we can't get parts and we have to look for part numbers. It happens on a weekend, usually, when we are sitting at home, comfy and cozy, perhaps sipping a beverage, and its 10° below outside. It probably could have been prevented by a regular inspection.

Ordinary Maintenance

We decide to walk around the plant we don't have anything better to do. It is noticed that a certain piece of equipment is making an unusual noise and getting hot but we don't report this we have a pretty full schedule this month and anyway we don't have to mark it down on a report to head office they don't require it. The end result is often disasterous not only money wise but could maybe put a small town out of water when they need it most.

## PORTRAIT OF A PRETTY PLANT

Let's stroll around this pretty plant,
We've nothing else to do;
So the motors make a funny noise,
They shake, they're hot, it's true.

But let us not report the fact,
(Head office wouldn't care),
And our schedule's pretty full this month--
We can always get a spare.

So let the water for the town,
Fall far below its need.
The Government can pay for it--
Oh, it's pretty plant, indeed.

### Preventative Maintenance

Is a regularly scheduled inspection and dismantling of equipment to check every point likely to cause trouble.

With electrical equipment, it involves orderly routines of testing, cleaning, drying, adjusting and lubricating.

For efficient control each piece of equipment should carry a card on which all tests and repairs are recorded. A sound preventative maintenance and recording system will prolong the life of both old and new apparatus.

It also enables the operator to look back on tests made some months previously. He can immediately detect any changes from that time.

A psychological aside regular testing of equipment becomes boring. Tests never seem to vary. They don't match the excitement of running around town trying to catch up with the electrician or even getting that reliable fellow out of bed at 3:00 a.m.

If you are the type of person who is an early riser, enjoys working in sub zero weather, and delights in annoying people in the wee hours, we would suggest that preventive maintenance is not for you.

## INSTRUMENTS FOR TESTING MOTORS

On examining a motor it's essential to test the insulation resistance of the windings, and the cables running to the motor. This test is made with an instrument known as a "megger". It measures the resistance that the insulating material offers the path of electricity to ground. As a general rule for every 1,000 volts there should be a minimum reading of one million ohms to the instrument.

You've probably seen a megger. The scale on the small, more generally used, model reads from zero to infinity. This megger has a built in direct current (D.C.) voltage output which is connected to the electrical equipment under test.

This D.C. voltage causes a small current to flow through and over the insulation being tested. In turn this small current leakage flow is measured on a resistance meter.

Ohm's Law shows that the current increases or decreases as the insulation resistance or the voltage varies. The Law is expressed by the formula:

$$I = \frac{E}{R} \qquad \text{or} \qquad R = \frac{E}{I}$$

where: I = The current flow in amperes

E = The voltage in volts

R = The resistance in ohms

In other words if the insulation resistance decreases the current leakage will increase. The voltage being a constant. This increase in current leakage causes heating and eventual breakdown in the insulation of the equipment.

In the normal application the insulation resistance tester has a small crank on the side of the unit which has to be cranked steadily for approximately one minute to overcome the inductive capacity of the equipment to be tested.

For the lazier types a small, electrically operated unit (motor driven) saves a lot of hand cranking since all that has to be done is press a button and let the unit do the work.

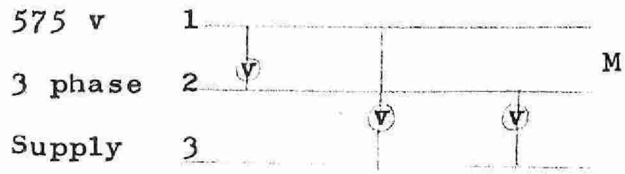
An insulation resistance tester should be connected so that one lead is connected to the conductor to be measured, and the other lead is connected to the ground. Ensure a good ground with the terminal or connection clean or free from paint. Always make sure no voltage is present on the system. Before carrying out this test make sure that all associated circuits are switched OFF.

Voltmeter

A voltmeter is used to measure electrical pressure or volts. It has a high resistance coil allowing small amounts of current to flow and deflect the pointer on the scale.

Voltmeters can be portable or fixed, some control panels having them mounted on the front to make recording easier. Electricians and Technicians use voltmeters to trace faults in a circuit, progressing from one point to another untill the fault is found.

When using a voltmeter, it should be connected in parallel with the source whose voltage is to be measured.




In the illustration we have taken an average situation. A supply usually three phase 575 volts supplying the motor with power to drive it.

When a voltmeter is inserted between each phase the reading should be 575 volts. In some cases hydro supply (depending on the location) is high or low but usually it is within 10% of the rated voltage.

Most voltmeters have various ranges of voltages to choose from so before attaching the meter you should know the approximate voltage to be measured. Don't overload the meter by putting it on the wrong range.

Ammeter

A device used to measure the current flowing in a circuit. Current is an indication of the loading factor of a motor.

When testing the equipment the full load current of the device can be taken from the name-plate and compared to the readings on the ammeter. If the current is higher than indicated on the name-plate you should immediately check the equipment mechanically and electrically.

The most common meter is an Amprobe this has several scales varying from 0 - 300 amps. To use the instrument you clamp it around the cable feeding the equipment and take a direct reading.

When working around electricity never take anything for granted, treat electricity with respect never get too familiar with the operation. If you always double check and investigate before testing you can be sure that yourself and the equipment will be safe.

# OILS AND GREASES

E. W. Weaver

B. A. Oil Co.

## CARE AND HANDLING OF LUBRICANTS

All reputable Oil Refineries exercise every possible care to see that their lubricants reach the user in an uncontaminated condition. From this point on the user must take great care to ensure that precaution to prevent contamination are carried out. We hope that this paper will help avoid expensive repairs and shut down caused by faulty storage and handling of lubricants.

## STORAGE OF LUBRICANTS

Outdoor storage of lubricants should be avoided if at all possible. Weathering soon obliterates labels, etc. and can lead to improper selection of products.

Drums should never be stored on their end because of likelihood of contamination with water especially where water has been allowed to stand in the rim and thus is sucked in past the bung as the drum and contents expand and contract due to weather.

Extreme cold, or heat, can also change the nature of some compounded oils and emulsions, thus rendering them useless.

In cases where drums must be stored outside the following precautions are advised:

1. Lay the drums on their side if possible.
2. If the drums must be placed upright they should be tilted slightly, and the bungs at right angles to the ground, to prevent water from collecting around the bungs.
3. A tarpaulin should be spread over the drums to keep out the weather.
4. Bungs should be kept tight.
5. Before removing any bungs, the heads of the drums should be completely cleaned of all grit, sand or other materials which may contaminate the lubricating oil later.

## WAREHOUSING AND DISPENSING LUBRICANTS

Drums in the Warehouse should be stored on racks with a suitable spout or if barrel pumps are used care should be taken that spillage is not too great.

Lubricants may be drawn from the above package with faucets, drain pumps and high boys for dispensing oil.

Grease dispensing presents a very different problem owing to the heavier consistency of the greases. This often calls for the use of open head drums and when opened, such drums are likely to collect dust and other contaminants. These contaminants do not settle down in grease but remain in suspension and are carried to the pumps thus causing damage.

These contaminants are just invited by the main method of using paddles to scoop grease from the open top drum. If paddles must be used we recommend metal paddles and a separate paddle should be used for each different grade or blend of grease and they should be stored in such a way as to eliminate any settlement of dust or dirt on them during each use period.

Suitable gun loading facilities used to fill grease guns which are equipped with covers for easy closing are recommended to eliminate the contamination problem. We also suggest the use of lube tubes where possible, thus again eliminating any possibility of contamination.

## CONCLUSION

Good housekeeping, particularly as it applies to the storage, handling and application of lubricants is a paying proposition in any plant or industry. Without it, it is impossible to obtain effective economical lubrication.

The subject is vast and complex and we have only highlighted some of the problems in this paper.

One subject which warrants particular study is the use of a purifier to maintain the quality of lubricants in service, another is the increasing use of centralized lubrication systems for the application of measured amount of lubricant from one central pouring station to each of the wear points of a piece of equipment.

# LUBRICATING GREASES

## HISTORY

Of all the products in the Oil Industry today possibly none have had as long a history as that select group we know as Grease, the ancient Egyptians some 4000 years ago used grease to lubricate their chariot wheels. Archeologists have found in the axles of the chariots a grease mixture based on the saponification of animal fats with potash.

## WHAT IS GREASE?

Lubricating greases may be looked upon as "a sponge for holding oil." The soap base forms the sponge framework and the type of soap determines the water resistance and useful temperature range of the grease. Into this blend is put the lubricating oil to provide all the lubricating qualities.

## CHARACTERISTICS

Greases are preferred in certain application requiring lubrication because of characteristics imparted by the soap base.

1. Greater adhesion
2. Better seal against entry of dirt and water
3. Resists leakage and drip-off
4. Cushions shock loads, resists being squeezed out
5. Greater load carrying ability
6. If of suitable base it will withstand water "wash off".
7. Due to stiffer consistency it can more readily hold in suspension additives which enhance certain desirable characteristics.

## TYPE OF GREASES

It is generally considered bad practice to mix greases and we strongly recommend against this practice. There are exceptions of course but these should only be carried out after a discussion with your Lubrication Engineer.

Listed below are common soap bases and the general properties of grease made from them. Properties shown are typical and will depend to a great extent on the viscosity and pour point of the oil used in manufacture.

| | | |
|---|---|---|
| 1. Calcium | Water Resistance | Good to Excellent |
| | Texture | Smooth |
| | Melting Point | 190 to 210 |
| | Useful Operating Range | -20 to +160°F |
| | Mechanical Stability | Poor |
| 2. Sodium | Water Resistance | Poor Emulsifies |
| | Texture | Smooth to fibrous |
| | Melting Point | 350 to 500 |
| | Useful Range | -20 to +250°F |
| | Mechanical Stability | Good |
| 3. Barium | Water Resistance | Excellent |
| | Texture | Fibrous |
| | Melting Point | 350 to 400 |
| | Useful Range | -20 to +250°F |
| | Mechanical Stability | Good |
| 4. Lithium | Water Resistance | Good |
| | Texture | Smooth |
| | Melting Point | 350 to 400 |
| | Useful Range | -60 to +250°F |
| | Mechanical Stability | Good |
| 5. Bentone | Water Resistance | Good |
| | Texture | Smooth |
| | Melting Point | None |
| | Useful Range | -30°F to Flashpoint |
| | Mechanical Stability | Good |

## SPECIAL GREASES

Over 99% of liquid lubricants used in todays greases are petroleum oils. The balance of the liquid lubricants are synthetic such as: Diesters, Silicones, Polyalkylene Glycols and Fluoro Carbons. However, these synthetics are employed only in special applications where the extremely high cost is secondary to performance characteristics.

Fillers such as Graphite and Molybdenum Disulphide to mention two are also used to enhance the basic grease characteristics.

# LUBRICATING OILS AND GREASES

E. W. Weaver, Supervisor
Product Application

The British American Oil Company Limited

## INTRODUCTION

All petroleum products are derived from Crude Oils.

Crude Oils vary chemically according to the predominating type of Hydro-carbons (from 40 to 60%). They are classified as paraffinic, naphthenic, aromatic, and mixed base.

Paraffinic and naphthenic are used for lubricating oils and grease.

Aromatic are used for asphalt
Mixed basis have all three above

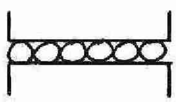
For our discussion we will use only Paraffinic and Naphthenic oils.

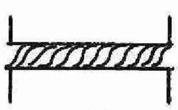
## LUBRICATION - What is Lubrication?

Lubrication is the ability of a medium to overcome FRICTION.

## FRICTION - There are three basic forms of friction:

1.  Sliding Friction - one solid body over another (i.e. two steel plates).

2.  Rolling Friction - (i.e. Ball or Roller Bearings).

3.  Fluid Friction - (Friction in the Fluid Only).

For our discussion we will use the latter (i.e. Fluid Friction).

## TERMS USED IN PETROLEUM INDUSTRY

VISCOSITY - is the measure of a fluids "FLOWABILITY". (e.g. Molasses would be considered to have a high viscosity. Water would be considered to have a low viscosity).

GRAVITY - is the weight of a substance.

Specific Gravity - is the ratio of weight of a given volume of material in air, to the weight of an equal volume of distilled water in air.

API Gravity - is an arbitrarily chosen scale in which the specific gravity of pure water is taken as 10. Liquids lighter than water have values less than 10.

VISCOSITY INDEX - is a measure of the rate of change of viscosity with temperature.

CLOUD POINT - is the temperature at which paraffin wax or other solidifiable compounds in oil just begin to come out of suspension.

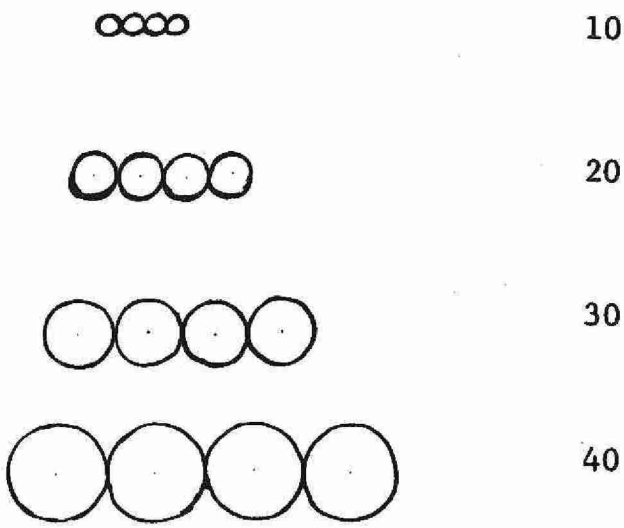
POUR POINT - lowest temperature at which an oil will flow.

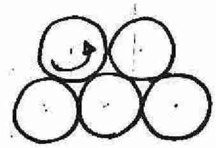
FLASH POINT - is the lowest temperature at which there are sufficient vapours to ignite.

FIRE POINT - is the lowest temperature at which an oil ignites and continues to burn for 5 seconds.

BALL BEARING THEORY

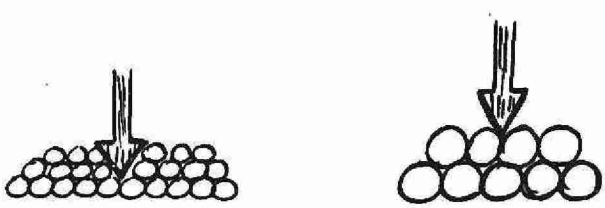
If we represent a lubricating oil by a series of ball bearings, we can then denote the oil weight by the relative ball bearing size.



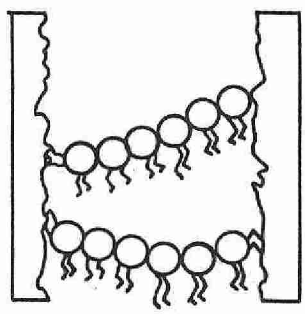
When an equivalent load or force now acts upon ball bearings of different sizes, we find that it is much more difficult to displace the large ball bearings.

By the same means, a heavy grade oil will more effectively overcome a direct load.

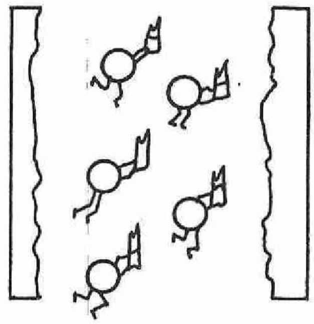


# THE FIVE FUNCTIONS OF AN OIL

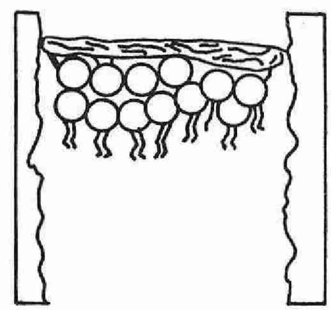
1. TO LUBRICATE



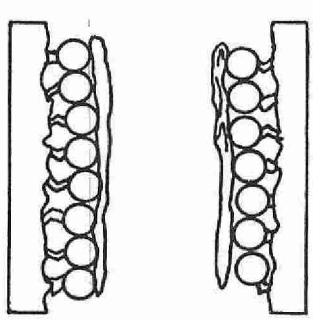
2. TO COOL



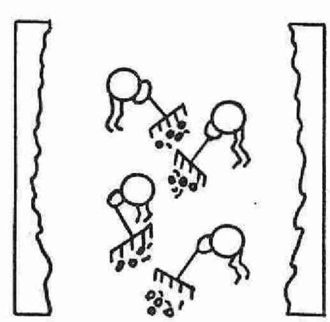
3. TO SEAL



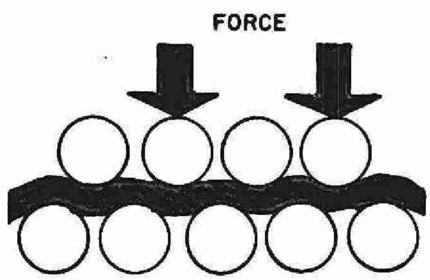
4. TO PROTECT



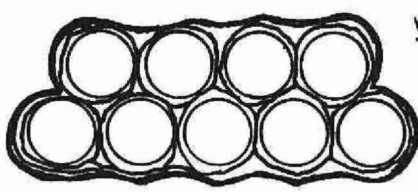
5. TO CLEAN



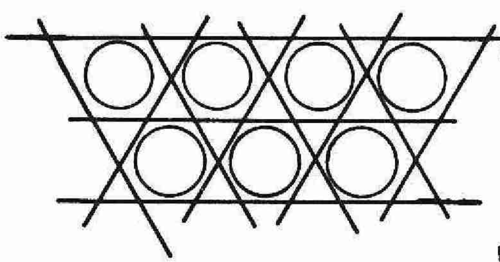
## VISUAL INTERPRETATION OF ADDITIVES USING BALL BEARING THEORY




E P ADDITIVE — Could be visualized as a thin piece of plywood.



V I IMPROVER — Could be visualized as rubber band completely surrounding the balls.



ANTI WEAR ADDITIVE — Could be visualized as sticks randomly spaced in bearings.

POUR POINT DEPRESSANT — Could be visualized similar to V I Improver except each ball would be surrounded by lubricating film to stop coagulation.

## OXIDATION THEORY

BRITAMLUBE 44: FLASH = 405: OXIDATION = 500 Hrs.

OXIDATION STARTS AT 160°F: DOUBLES EACH 18°F.

| TEMP. °F. | °F. INCREASE | OXIDATION (HOURS) | HOURS LEFT | DAYS LEFT |
|---|---|---|---|---|
| 160 | - | 1 Hour | 500 | 20 |
| 178 | 18 | 1 + 1 = 2 Hours | 250 | 10 |
| 196 | 18 | 2 + 2 = 4 | 125 | 5 |
| 214 | 18 | 4 + 4 = 8 | 62½ | 2½ |
| 232 | 18 | 8 + 8 = 16 | 31¼ | 1¼ |
| 250 | 18 | 16 + 16 = 32 | 16 | -2/3 |
| 268 | 18 | 32 + 32 = 64 | 8 | 1/3 |
| 286 | 18 | 64 + 64 = 128 | 4 | 1/6 |

## OXIDATION THEORY

BRITEX R. & O. 44: FLASH = 410°F: OXIDATION = 2000 HRS.

OXIDATION STARTS AT 160°F: DOUBLES EACH 18°F.

| TEMP. °F. | °F. INCREASE | OXIDATION (HOURS) | HOURS LEFT | DAYS LEFT |
|---|---|---|---|---|
| 160 | - | 1 Hour | 2000 | 84 |
| 178 | 18 | 1 + 1 = 2 Hours | 1000 | 42 |
| 196 | 18 | 2 + 2 = 4 Hours | 500 | 21 |
| 214 | 18 | 4 + 4 = 8 | 250 | 10½ |
| 232 | 18 | 8 + 8 = 16 | 125 | 5+ |
| 250 | 18 | 16 + 16 = 32 | 62½ | 2½ |
| 268 | 18 | 32 + 32 = 64 | 31¼ | 1¼ |
| 286 | 18 | 64 + 64 = 128 | 16 | -2/3 |
| 304 | 18 | 128 + 128 = 256 | 8 | 1/3 |
| 322 | 18 | 256 + 256 = 512 | 4 | 1/6 |

# EFFECTIVE PUBLIC RELATIONS

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Public relations by a water utility is communication with the general public and employees of the water works. It is an attempt to keep these people well informed of the accomplishments, developments, problems, needs and objectives of the public utility. In essence, it advertises the fact that it provides an excellent service so that it receives the appreciation it deserves and hence the good public image of the utility is enhanced. It will then have to maintain a constant vigilance of its liaison with the public to protect the good image it has created.

There are many reasons for maintaining a good public relations programme but, the most general is that it is "good common sense". The consumer wants to know how his dollar is being spent and in some cases the opportunity to vote on the acceptance or rejection of a major project. Of course there is a limit governed by the size of the municipality and necessity of the project whether their opinion is sought or not.

The manner in which such a programme is executed is dependent on various influencing factors in the municipality. For example, smaller municipalities are closer to the public and are able to deal with problems on a more personal basis than a large municipality. It is left to the discretion of the management of each water works system to decide on the most effective approach.

An effective public relations programme is often a direct reflection of management's ability and interest to get along with the consumer and general public. This fact may be noted by an industrial representative who is travelling through the town. He may be sufficiently impressed to consider that town for the location of a new plant. He realizes that good management is a reflection of good business. Hence, it can stimulate the economic growth throughout the entire community and in this way help to build and secure profit for all its inhabitants.

The discussion has so far been limited to the effects of external communications. It is just as important to maintain good internal communications or management-employee liaison.

It is "good sense" to develop in the employee a loyalty to the organization and an understanding of the goals it hopes to achieve. In this way the productivity of the employee is stimulated and he will work to his maximum level of efficiency to provide the best service he can. The realization of this fact is good management technique.

There are countless methods being used by municipalities in maintaining an effective public relations programme. Some of the rules to follow in accomplishing such a programme are now presented. We will deal with both aspects of communications, internal and external, since the effective execution of the latter is somewhat dependent on the former.

## INTERNAL COMMUNICATIONS

### In-service Training

A new employee whether it be a secretary, repairman, meter reader or plant operator should be properly instructed of the goals and purposes of the water works. The history, role, general operation, policies and future developments of the system should also be accurately outlined verbally and in written form by the supervisor or personnel officer of the employee. In many cases these employees will be your first-line of contact with the public.

Each man and woman in the utility family should know the component parts of the utility and their relationship to one another. They should be made to realize that they are an integral part of the organization and help make the utility operate. If fully informed of the operation of the water works, the employee can accomplish a great deal in promoting public understanding and appreciation of the efforts of the utility.

In addition, all the other employees should also be kept up-to-date of recent developments, problems and future proposals.

One method of transmitting this information is by publishing a newsletter on a regular basis. Bulletin boards should be available in employee traffic areas where news bulletins which affect the status of the employees can be placed.

Retired employees should also be sent copies of these employee publications. They too may be interested in the progress of the water works and can be utilized as valuable assets in the

public relations field.

Routine Management-Employee Meetings

Regular discussion sessions should be held between the management and the other employees of the water works. This enables all the workers to openly voice their complaints, express their views, suggest ideas and generally keep abreast of any proposed modification of the water works or organizational structure.

The provision of a suggestion box is another method of allowing employees to list their complaints on record.

Public Relations Seminars

The purpose of a public relations seminar is to train the personnel in this aspect of their occupation.

Secretaries and switchboard operators should be taught proper telephone courtesy when talking to the public. They should be knowledgeable of all general particulars of any detours caused by repairs or installations of water pipe lines. She should know how long the public will be inconvenienced, the capacity of the new main, the name of the contractor who should be contacted if more pertinent data is required, etc.

Meter readers and repairmen should especially be well acquainted with the operation and progress of the utility. They come into regular direct contact with the consumers and hence may be asked to answer many pertinent questions. They should also realize the importance of proper etiquette, cleanliness, manners and neatness when dealing with the householder. Some plants provide uniforms for their employees and this practice merits careful consideration by the utility managers. This is to protect the customer from those who would represent themselves as water works employees to gain entrance to the property.

Selection of Duties for Operators

All the operators at a plant should be informed of the mode of operation of all various units at a water works and their function in the treatment process. In case of an unexpected visit by a civic official, government representative or any other official delegate of some agency,anyone in the plant would be able to direct the plant tour.

People naturally expect the water works and its surroundings to be continuously kept in a neat and clean condition. They may not know the inner workings of a utility but they do take pride in an attractive water works plant. It is up to the operators to keep it so.

In selecting the various duties for the operators, the supervisor should be aware of any particular interests of the employees. For example, if one has talents in gardening, painting, photography or any other related interests or hobbies that would be useful at the plant, this should act as a guide in the selection of his duties. It will give the individual a greater pride and inspiration in his work if it is tailored to suit his interests.

## EXTERNAL COMMUNICATION

We have discussed several methods of maintaining an internal communication within the utility. Now with a well instructed staff, this atmosphere or knowledge will tend to permeate to the general public.

### Keeping the Various Public News Media Informed

Most news media welcome the help of legitimate publicity, which, for the most part, is beneficial to both parties. The utility should take advantage of any good publicity they can obtain. The common news media that can be accredited for this publicity are the local newspaper and radio and television stations. They are interested in personnel changes, transfers, awards, plant tours, open houses and other events of interest. You can assist men associated with these media by submitting items which you are reasonably sure are of public interest.

You should maintain a good contact with members of these news media. One man from the plant should be selected to be responsible for publicity. The utility should help him in developing an effective technique in writing or giving interviews. He may also assist in the production of a regular newsletter or other work of this nature.

### Customer Complaints

Customers must be able to reach the utility to voice their attitudes and complaints. The response in all these circumstances must be friendly and patient. The complaints should

be effectively handled as soon as possible and, if need be, followed up at a later date.

Telephone manners when dealing with a complaint cannot be overemphasized. The dissatisfied customer will tend to be less harsh when the person he is talking to radiates a spirit of warmth, enthusiasm and understanding over the telephone. It isn't intended to imply that one should be artificial in such a case. On the contrary, he should appreciate the problem the complainant is experiencing, be able to discuss the situation intelligently and try to offer an immediate (even though it may be a temporary) solution to the problem. Ideally, in some cases, it may appear that you require a machine to possess the above qualities when dealing with an irate customer. Not really - but it does require the selection of a patient person who has a genuine feeling for his job and a naturally gifted knowledge of human relations.

A factual record of the conversation should be made and passed on for processing.

Proposing an Increase in Water Rates

Eventually a water rate increase will be imposed on the users. A good service record and a knowledgeable public gives convincing support to the technical case for a rate rise. In the event of a proposed rate increase the following steps are suggested:

1. A postcard notice is sent to each customer and a letter to each employee outlining the reason for the increase.

2. The necessity for the increase is publicized over the various news media.

3. A more detailed explanatory letter is sent to each large consumer.

4. Local industries and hospitals are notified as well in advance as possible to allow them to consider the budgetary impact of the increase.

The utility may also include a chart showing the progress of the water works, the financial comparison of operation, between various years, a distribution of the revenue dollar and the increased water use and pumpage over the years with their letters to the consumers. A present or proposed map of the area and population to be served should also be included to enable the

people to realize the tremendous water demands of the growing municipality.

If there is a choice to either (1) impose no present increase in water rates and deliver a water of past quality or (2) to impose a pre-calculated rate increase and serve a water of improved quality, the decision of the consumer can be determined by conducting a postcard survey.

Signing

A courteous maneuver, if a road is to be torn up for the installation or repair of water mains, is to conspicuously locate signs apologizing for the detour. Also inform the traveller as to the length of time the project will take, the reason for the detour, etc. If you are expanding the size of the main, give general particulars of the new size of pipe, its increased capacity, and who to contact if more information is required. This is why, as mentioned earlier, the telephone switchboard girl should be familiar with the project. This approach will be one of the most effective ways of informing the public of the progress of the community.

The water utility should consider designing a symbol to represent the water works and using it wherever applicable. It should be borne in mind, however, that the OWRC symbol may not be used for any purpose by anyone other than Commission personnel.

Plant Tours

Plant tours or open houses are most essential in creating a desirable public utility image. Open houses are generally held to celebrate a plant birthday, community anniversary or some such event and the entire community is invited to visit the plant. Plant tours are arranged to appeal to a select group such as teachers, students, civic groups, members of organized clubs, etc. Programmes for these tours are designed to fit the interest of the specific group.

Tours should be encouraged by the plant operators and management. In addition to the obvious public relations benefits of conducting a plant tour, it stimulates and encourages the operators to keep a neat house and well maintained equipment.

When planning a plant tour set a definite theme and incorporate your objectives but don't confuse the visitors. In

general, give broad impressions and keep the programme simple. Remember the purpose of the tour is to teach and not to dazzle the visitors with your knowledge and technical terminology of water treatment. Some points to keep in mind when planning a tour or open house are given below.

1. General Housekeeping - Keep the yard, entrance and plant clean and neat. The erection of a welcome sign is a friendly gesture.

2. General Description - Prepare the visitors for the tour by describing the general treatment process with reference to a wall-size schematic diagram which should be available at the plant. The function of each unit can be commented on while using this visual aid.

3. Groups - Split up the group into smaller parties, preferably of six or seven people, or depending on the number of guides available. The guides will probably consist of the plant operators. Therefore they should be thoroughly familiar with the operation of the plant and treatment units. If necessary use a film to describe the process.

Routing

Signs with arrows showing the simple direct route to be followed by each group should be established. It may be helpful if a short explanation of the function of each unit is described on a placard and displayed at the respective units.

Transportation

Arrange for ample parking space to be available to accommodate the cars and/or buses required to transport the guests.

Souvenirs and Refreshments

Inexpensive souvenirs (key chains, note books, plastic drinking cups with the water works symbol, etc.) may be given to the groups as a tangible reminder of their tour and help to create a good feeling towards the utility system. Some refreshments may be served if practical. They don't have to be elaborate. At this time, a period could be planned to discuss their tour to somewhat more detail now that they are more knowledgeable about the treatment process. The guests should be requested to sign a visitor's book.

## Promotion and Publicity

News stories accompanied with photos of the group and follow-up letters to the group representatives should be carried out. It may be an idea to take a photograph of the group and send them a copy, when developed, and also pin a copy on the visitors' bulletin board.

## General Assessment of Tour

The tour should be evaluated carefully and objectively by the organizers so that the subsequent tour can be improved.

# CONCLUSION

The object of this presentation is to make one aware of the need of an effective public relations programme for the water utility. Several methods of augmenting the present programme in effect in a municipality are presented. It is by no means implied that the programme is restricted to the methods discussed. There are virtually countless ways of promoting good public relations and the most effective methods may be different in each municipality.

You may find that, in the initial stages, the effort will be costly but, ultimately, is less expensive than to permit people to form false impressions and distort the facts through ignorance. One of the best ways of maintaining a good public image is to keep the people well informed as to the manner in which their money is being spent. Public relations is adequate when the people are confident that the utility's programme is sound in engineering and economically feasible.

You should make a personal evaluation of the effectiveness of the public relations programme established by the water works in your community.